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THE ICE PLANE.

THE alternations of cold and thaw that have recently been occurring, having made the surface of the ice rough and uneven, have forced skaters to put their wits to work to find a remedy for this state of things. They have succeeded in this, thanks to an apparatus unknown in France before the Skaters' Society adopted it.

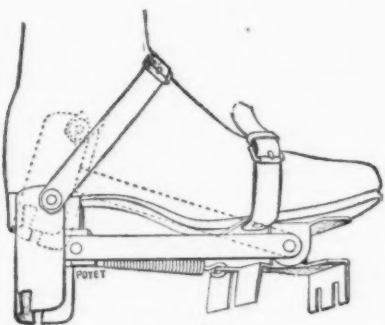
This apparatus, called the ice plane, comes to us from Vienna. Its name indicates the use to which it is put: It serves for planing, sweeping, and smoothing the ice over whose surface it is drawn.

It is, in definitive, as may be easily seen from the diagrammatic figure that we give herewith, a plane of large dimensions, whose iron is situated in front. The whole apparatus is arranged with a view to facilitating the action of this iron.

The ice plane consists of a wooden frame formed of four uprights, connected by two longitudinal pieces, one at the bottom and the other at the top. The lower one of these, which is but a few inches above the surface, is provided in front with a strong iron beak, terminating in a socket, in which is fixed a transverse iron bar that supports at each extremity a square block of wood, which, owing to a screw that traverses it, may be elevated more or less. This ensemble serves as a sliding base, and presents a solid point of support. Beneath the



FRONT VIEW OF THE ICE PLANE.



ICE SHOE.

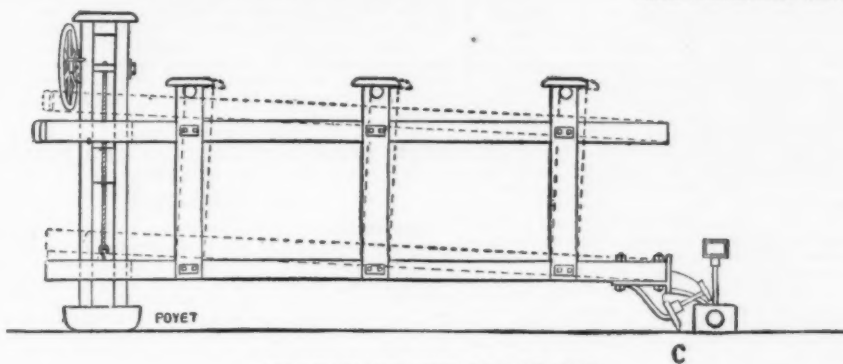


DIAGRAM OF THE ICE PLANE.

beak, and behind the blocks of wood, a small bent rod supports the steel blade, about a yard in length, designed for planing the surface of the ice.

The first three uprights are traversed by bars of wood that permit three men on each side to push the plane forward. As for the posterior upright, which is thicker and higher than the three others, that is traversed at its upper part by an iron rod, actuated by a hand wheel, and around which winds a cord that lifts the whole back part of the machine, more or less, and makes it oscillate slightly on an imaginary axis situated near the beak. This permits of making the blade oblique or of rendering it perpendicular to the surface of the ice that it is to plane, in order that it may have its maximum of action, as the case may be. A special man actuates the hand wheel, while a steersman, standing alongside of him, and pushing a wooden bar to the right and left, directs the plane.

Our engravings show the apparatus in operation. Under the impulsion of its crew, it traverses the surface to be rendered even; and the ice, in small shavings and in the form of



SIDE VIEW OF THE ICE PLANE.

snow, flies before and on each side of the blade.

The men are provided with an ice shoe, which permits them, thanks to the teeth with which the sole is provided, and to the peculiar form of its sharp-edged heel piece, to obtain a good, firm hold on the ice. A small joint connects the front of the shoe with the back, through a strong spiral spring, and in this way the play of the foot in walking is freely effected. The dimensions of the plane naturally vary with the effects to be obtained.—*L'Illustration*.

THE INVENTION OF THE KNITTING MACHINE.

THERE does not appear to be much doubt that the first attempt to supersede the knitting of fabrics by hand was made by William Lee, in the year 1589, and although the French are disposed to claim this honor for themselves, it is quite certain that it belonged to Lee. It is true that the first practical step toward the employment of his machine was taken by Henry IV. of France, who encouraged Lee in the development of machine knitting in Rouen.

Religious bigotry, after Henry's death, asserted itself, and drove the invention back to its native country, but, so far as English encouragement was concerned, it was for a long period non-existent. It is most remarkable that the very es-

sence of Lee's invention is the use of a barbed needle, just as the essence of the modern sewing machine is a needle with an eye at the point. At this early stage this apparently simple but really difficult problem was attacked and solved by Lee, and without it the possibility of forming loops by machines would have been well high impossible. By the use of this device the passage of a loop through one previously formed was readily effected. Having accomplished this somewhat difficult task, the next stage was to form a number of loops at once, and interlock them. Obviously this could only be done by mounting a number of needles so as to be simultaneously elevated and depressed. As a corollary to this there was the necessity for opening and closing the whole of the beards at once, so that the loops as they were formed could be passed off the needles. The formation of the loops was effected on the stem of the needle by using jacks and sinkers, by which the thread was depressed sufficiently to form a loop, and subsequently to pass the loop under the beard. The parts devised by Lee, especially the bearded nee-

dle, sinkers, and jacks, are in their essence identical with those used in most of the machines made to-day.

Shortly after the return to England of Lee's companions, various other improvements were made by them, among them being the invention of lead sinkers, in 1630. No more convenient method than this has ever been devised, and these early pioneers of a great industry thus showed their prescience by inventing almost every essential feature of latter-day machines. The result was soon seen in an enormous development of frame knitting, and during the protectorate of Cromwell a charter was granted to the company of frame workers. Subsequently to this date the next onward step was the invention, in 1758, of a machine for making ribbed stockings, by Jedediah Strutt, of Belper. This machine proceeded upon the principle of selecting some of the threads for special treatment, and using them to form loops in the reverse direction to the ordinary ones. Strutt's invention was an amplification of Lee's, and, although important enough to be called a new one, left untouched the main principle of Lee's.

An important advance in machinery of this character was found in the invention in 1775 of the warp knitting machine, by which every needle was provided with a thread, and a series of loops thus formed. This machine really produced a sort of cloth which could be cut out into any shape and sewed into garments. The essence of the warp knitting machine was the method of traversing the needles sideways, so that the various chains of loops as they are formed are fastened together. The warp frame has been largely improved by a long series of inventions, and exists in several forms to-day. It has not, perhaps, come into such extensive use as the ordinary form of machine, but it possesses a few characteristics which make it very valuable.

It may be fairly said to be the progenitor of the modern lace machines, and in that form has been much more widely used than for hosiery. Still, in later days, the power of varying the size of the meshes, which is the central feature of the warp machine, has been advantageously employed, and has found its fullest development in the wonderful warp knitting machine of Mr. Arthur Paget, exhibited at the Paris Exhibition, and described in these columns.

The next most important step was the invention by William Dawson, in 1791, of a means of giving the lateral movement to the warps by a rotary part. He devised the notched wheel operating upon bolts or bars and pushing them out. By varying the character of the notches, it is possible to get almost any range and variety of motion, and this device has been successfully used for many classes of work. By means of a modification of his mechanism, Dawson found that he could plait stay laces at a high speed, and this was the chief use he made of his invention. Except for the limitations which are consequent upon the mechanism, Dawson's wheel was capable of performing the same part as the Jacquard machine, but is not, of course, equal to that in the infinite variety of combinations of threads. The fact remains that this simple piece of mechanism solved a problem of great difficulty, and in a modified form is in use to-day, but principally in lace making.

This brief sketch shows that so far back as the end of the last century most of the essentials of knitting machines had been invented. It is very remarkable how close a connection exists between the principles of lace and hosiery machines of the warp type. It is true that there is the difference between the formation of a loop and the twisting or intermeshing of two threads, but in essence there is little distinction. The student of this class of machines must be struck with the number of times inventions designed for the production of looped or knitted goods have been diverted to the manufacture of lace nets, and if nothing else existed, this fact alone would show the very close connection existing between the two machines. Until the age of mechanical refinement—as it may be called—is reached, the successive inventions of the bearded needle, presser, sinker, and jacks by Lee, of the lead sinker by Aston, the ribbed knitter by Strutt, the warp machine by Tarrant, and the notched wheel by Dawson, practically include every essential feature of modern machines. Since that time the range of action of the parts has been widened, their accuracy improved, and their velocity increased, but the improvements have been mainly devoted to refining the details.—*The Textile Recorder*.

PROFESSOR MARTENS ON DROP TESTS.

By GUS. C. HENNING, M.E.

IN *Zeitschrift des Vereines Deutscher Ingenieure*, xiv., 48, are given a résumé of Buckling's tests, made with a drop test apparatus, by Prof. A. Martens, director of the Royal Testing Laboratory at the Polytechnic School at Charlottenburg, Berlin, Germany. The results of these tests, which were commenced in 1885, have demonstrated that they are quite sufficient to determine the properties of materials accurately. With proper precautions and care these tests are exact and reliable. Several series of tests have demonstrated that they can be made with great exactness, and that errors are less than 0.5 per cent., whether cubes 0.5 in., 0.6 in., or 1.2 in. are used. Steel rails and tires for drivers, followers, and car wheels, cast iron, wrought iron, low steels, copper, aluminum alloys, white metal, magnesium, and others, were tested in similar manner, and all of these results are reported and plotted in full. The report is a masterly piece of a most exhaustive and carefully made investigation.

It was proved that distortion due to percussion or compression was the same, and variation of shapes identical, when tests were correctly made and errors of manipulation avoided. Different shapes, such as cubes, tubes, and short columns, were also compared, and the uniformity of shape of distortion was remarkable.

The material was, furthermore, tested at different temperatures, and after having been subjected to different treatment. In this respect it was found that when experimenting with three grades of low steels they all showed highest resistances for similar distortions at a temperature of 302 deg. F., while tensile tests of the same materials show the greatest resistance invariably at 302 deg. F. The curves plotted corroborate Kieck's law: That a few intense blows produce greater effect than a greater number of light blows of the same total work done.

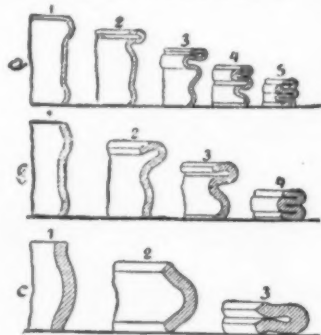
It is shown that test pieces must be made strictly

like the standard form, and allowable variation must be very small, otherwise results of tests will be considerably affected; this effect, due to variation of form, is not as noticeable under the early blows as it is later on. Slight variations of form must be counteracted by change in height of drop of weight. Cast iron is found to show greatest resistance when subjected to repeated blows, due to identical height of drop of weight. Resistance decreases under several blows preceding that one which produces failure. The elastic distortions in cast iron remain almost proportional up to point of failure, but vary for differently shaped bodies.

Heavy blows produce greater effect than lighter blows of the same total work done. Height of recoil of weight or ball is but slightly greater for light than heavy blows.

All of these tests, as well as those on low steels previously referred to, prove the practical utility of drop tests, which is emphasized to a greater degree by the figures below, showing results of testing hollow cylinders.

For these tests pieces of tubes made of a high steel



were cut off so that the length was equal to extreme outside diameters and surfaces were truly normal to axis of cylinder.

Distortion is quite characteristic for different shapes, and this was almost the same as that obtained by compression tests, so that a similar amount of depression produced the same changes of form as shown in the figure, and this without causing failure, slight cracks sometimes appearing when bent to the final shape.

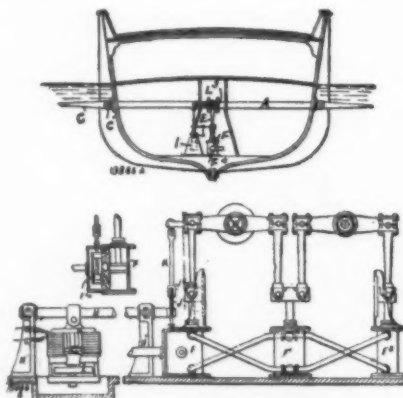
The law of proportionate resistances is also verified by these tests, and they demonstrate that: Geometrically similar bodies of the same material, subjected to similar numbers of specifically similar amounts of work due to blows thereby, undergo changes of form geometrically similar and equal per cent. of changes of height. It is also seen that for steel these latter changes due to impact are proportionate to tensile resistance, and similarly that they are proportionate in elongation and contraction of section. In the case of cast iron but a slight increase of resistance to impact was noticed with increased tenacity. In the case of copper which had been annealed it was found that the consequent effect decreased with increasing number of blows, as change of form due to blows reheardened copper previously annealed.—*Engineering and Mining Journal*.

PREVENTING THE ROLLING AND PITCHING OF SHIPS.

By H. S. MAXIM.

THE ship is provided with fins projecting on each side, and forward and aft, in a horizontal direction below the water level. A gyrostat is employed to govern, through the medium of a steam motor, these fins, so that they will form inclined planes, which, by their action on the water as the vessel moves through the waves, will tend to prevent the rolling and pitching of the vessel. The action of the apparatus shown is as follows:

Assuming that the ship rolls over to one side, then, owing to the resistance offered by the rotating gyrostat, I, to the change of its plane of rotation, the shaft, H,



to which the gyrostat is pivoted, will be prevented from turning in the space, but it will have a rotary motion relatively to its bearings, H', corresponding to the extent of roll of the ship. Consequently, the equilibrium distributing valve, F*, of the steam cylinder, F, which valve is connected to the shaft, H, will be moved relatively to the cylinder. One or other of the steam ports will thus be opened and steam will be admitted to one or other end of each of the cylinders, F and F', and to the opposite end of the cylinder, F', thereby operating the pistons and partially rotating shafts which are arranged with the tubes, A. By this action the fins, C, are so feathered that the forward edge of the blade on the descending side of the ship will be caused to point upward, while that of the blade on the ascending side of the ship will be caused to point downward. While the blades are thus feathered

the arm, D', is at the same time moved by reason of its attachment to the beam, D, and this movement, acting through the link, K, operates to rotate the lever, J', about its pivot at the upper end of the link, J', and thereby restores the equilibrium valve to its central position and closes the steam port.

WINTER RESISTANCE OF TRAINS.

At this season of the year, when traffic is nearly always heavy, and being this year phenomenally so, railroads are confronted with the fact that, because of the increased resistance of trains to being pulled in cold as compared with warmer weather, fewer cars can be hauled per train. Instead of increasing the tonnage hauled per train, as would be desirable in view of the great rush and recent blockade of traffic, trains must actually be cut down, according to the prevailing temperature, to two-thirds or one-half of the tonnage hauled easily in summer.

With the motive power and other facilities of a road heavily taxed to handle traffic with the ordinary weight per train, it often becomes impracticable, when the weight per train must be cut down, to increase the number of trains sufficient to handle traffic properly, and delays and blockades, with their attendant losses, follow. Thus it is that the effect of cold is to decrease the efficiency of railroads. In view of the losses that unavoidably follow, and the greatly increased expense of moving traffic, it appears that the cause that produces this disastrous effect is worthy of examination, and such discussion as may lead to a general understanding of it by all concerned, thereby possibly effecting some improvement. Yet, of all matters pertaining to railway rolling stock and the movement of traffic, there has been none so little discussed.

Friction acts in many different ways to retard trains in motion. By the friction of the air against the exposed surfaces of a train, the friction of the wheels rolling upon, and their flanges against the rails; by the friction of the rubbing surfaces of the locomotive's machinery, and of the axle journals of train and engine rolling against their bearings, the motion of trains is retarded, and, finally, by the friction of the brake shoes against the wheels, trains are brought to rest when desired.

There is another way in which friction acts to retard the motion of trains, and it is this form of friction almost absolutely that causes increased train resistance in cold weather, with clean rails. Fluid friction, the friction between the particles of a fluid in motion, in our case the friction between the molecules of the oil lubricating the axle journals of the train and engine and the external rubbing surfaces of the engine's machinery, is a form of friction that acts almost exactly the same as the friction between solids—and retards motion.

The resisting force of this friction in oil depends entirely upon its state of consistency, and in ordinary lubricating oils this depends entirely upon the temperature. Carefully conducted railroad laboratory tests have demonstrated that with a fall of temperature of 70° the friction was doubled with the same lubricating oil. The colder the oil, the greater is the viscosity, and the greater the viscosity, the greater the friction between the sticky layers of oil adhering to the journals and their bearings in rubbing against each other, thus increasing the resistance of the train to being hauled, making necessary a reduction in the weight of train, and, as stated, lowering the efficiency of the road.

The larger portion of the greater fuel consumption of locomotives in winter is also due directly to this cause, although the colder feed water, radiation, and colder air and fuel for combustion are important factors. Because of the friction in the congealed lubricating oil, locomotives use steam over many more miles of road each trip in winter than in summer. This is brought about in two ways. First, by causing trains approaching stations to "hang back" after steam is shut off, thus compelling the use of steam probably a quarter of a mile closer up to each station than is necessary in summer, and second, by preventing the trains from running down hill freely, compelling the use of steam while descending grades that in summer the trains run down several miles at the desired speed without any assistance from the engine.

The increase of locomotive fuel consumption due to colder temperature very materially increases operating expenses in winter. Carefully kept records of the variation of temperature and of locomotive coal consumption, on a prominent Western railroad, showed the average variation in coal consumption, per one degree of varied temperature for four years, to be 0.06 pound coal per passenger car mile and 0.03 pound coal per loaded freight car mile. At this rate a fall of 50 degrees in temperature would cause a freight engine to burn 15 pounds of coal more per car mile and a passenger engine 3 pounds more per car mile. If the freight engine hauled 18 cars 100 miles, the extra coal consumption would be 2,700 pounds, and if the passenger engine hauled five coaches 100 miles, the extra coal consumption would be 1,500 pounds. This is not very far from the actual results in practice. The average extra coal consumption of the engines in the two classes of service due to the colder temperature would be a little over one ton per trip of 100 miles. On a railroad operating 470 locomotives, each making 100 miles per day for a month, this excess in fuel consumption, as stated, would amount to over 14,000 tons, which, at a cost of say \$1.50 per ton, would be \$21,000.

On a railroad actually operating this number of locomotives the difference in coal consumption between July and January recently was actually 12,699 tons excess for January as compared with July, which, at the cost stated per ton, did amount to over \$19,000, and there was an average decrease in cars hauled of 0.59 car per passenger train and 1.89 cars per freight train, as compared with July.

Although it may be easier to indulge in a diagnosis of the disease than to name a remedy, we believe much can be done to mitigate the severity of the conditions described and to improve on present practice. It is not uncommon for locomotives to be supplied with and cars oiled with lubricating oil in winter that cannot be poured from the spout of a can at 30 degrees Fahr., and that at temperatures below zero, as we often have, can be cut with a knife like butter. Knowing that it is the friction of the congealed lubricating oil that mainly causes the greater train resistance of win-

ter, and all its attendant trouble and expense, it must be plain that greater attention should be bestowed upon the consistency of oil used for lubricating purposes with regard to the temperature at which it is to do its work.

Ordinary lubricating oils can be diluted with lighter oils, kerosene for instance, to any degree of consistency desirable, even when in contact with an ice cold surface; and it is desirable to have a liquid consistency of the lubricant when possible. Pure kerosene is declared by eminent authority to be a better lubricant for an ice cold surface than the best sperm oil. As it is cheap, it would appear then that its liberal use in diluting car and engine oils in cold weather as nearly sufficient as may be found practicable in service to maintain liquidity would greatly mitigate the vast trouble and expense of the increased resistance of trains in winter, for we may be assured that with no more friction in the journal boxes in winter than in summer, with clean or only frosty rails, locomotives can pull "summer trains" all the year round.—*Nat. Car Builder.*

PNEUMATIC DISPATCH IMPROVEMENTS.

The first pneumatic dispatch system in Berlin was established in the year 1876, similar to those then already in use in Paris and London, and since that time has grown to a considerable extension and importance. The conduits were first arranged according to the polygonal system, in which the single stations were polygonally connected with the central station, and the conduits were run through by the dispatch carrier boxes always in the same direction.

Some years' service having shown the insufficiency of the polygonal system, its transformation to the radial system was determined and gradually accomplished. With this latter system, the single stations are arranged radially round a common center, the chief office, where

The apparatus, which may be employed both for receipt and delivery, and also as transit apparatus, is represented by the annexed views. It consists essentially of a reception and delivery chamber M, which at its upper part is shaped elliptically and receives, accordingly as it is at a terminal or intermediate station, either one or two tubes. For supporting the chamber, two brackets are provided, which support at the same time a table in front of the chamber. In the one tube R a specially shaped cock F is intercalated, which, according to its position, either establishes communication between this tube and the chamber or cuts off the communication.

The special construction of this cock comprises a central perforation, and several smaller channels running from this central perforation into a hole at the lower end of the cock. From this hole a second channel parallel with the central opening crosses the wall of the cock, and communicates in a certain position of the cock with the tube S, which is in communication with the free air. The rotation of the cock is effected by bevel wheels, of which one is placed on a prolongation of the plug, and the other is connected by a vertical shaft to the hand lever H.

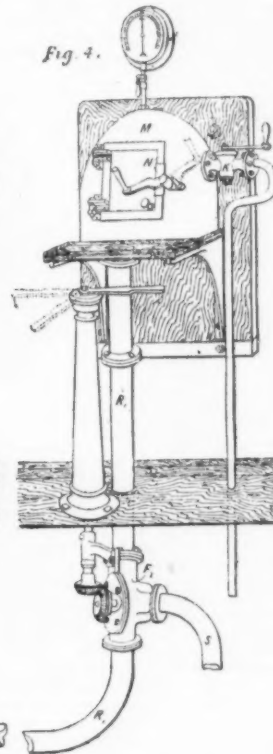
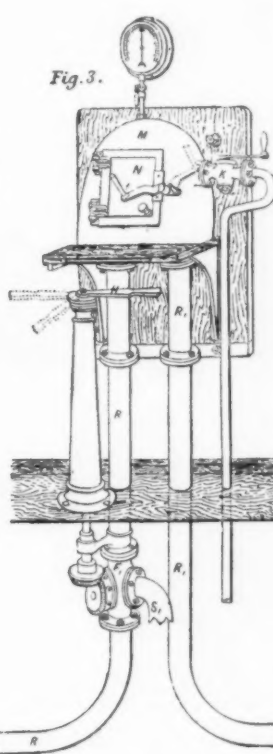
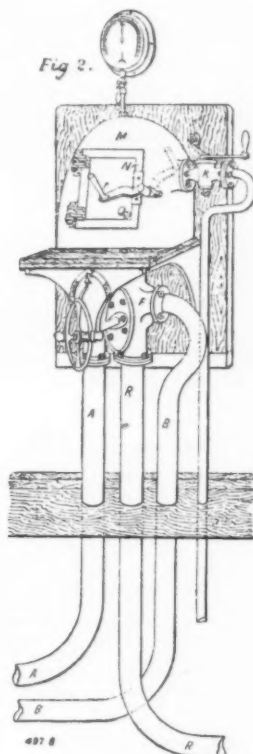
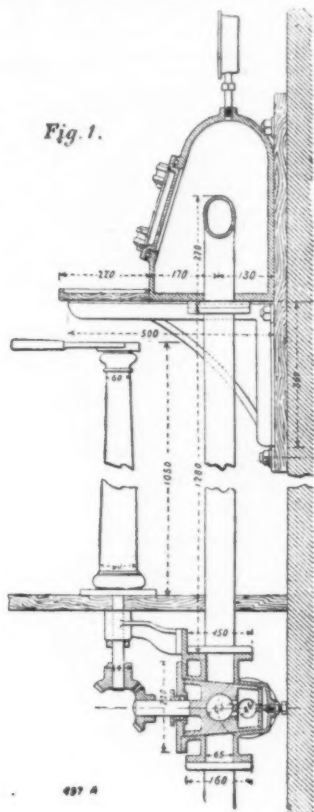
The column serves to support this shaft, and to limit the stroke of the hand lever H. On the face of the table which is turned toward the hand lever there are provided small plates with inscriptions indicating the different positions of the cock corresponding to the positions of the hand lever, so as to prevent any mistake.

The door N, which closes the chamber, is tightly shut by means of a lever, turning on the chamber against an oblique face of the closed door; besides this there is provided India rubber packing between door and chamber. The gauge indicates the pressure existing in the chamber, both above and below the atmosphere. The cock K, arranged laterally on the chamber,

sides of the chamber announces its arrival to the attendant. He turns the lever H, thereby cutting off the further current of compressed air into the chamber, and its exit through tube S opens the balancing cock K on the chamber, and finally the door. After having taken out of the carrier box the dispatches for his station and inserted those to be forwarded to the end station, the boxes are put into the tube; the door and cock K are then closed, and the cock F again put on "passage." The carrier box impelled by the compressed air entering through tube R and chamber into tube R' will hurry through the tube to the end office (Fig. 4). Here the attendant will withdraw it from the chamber in the way just described. During this time the passage cock at the central station remains open, and the cock F there remains in the same position, as the cutting off of the compressed air will be effected by the cock F.

After one or more carrier boxes have passed from the central station to the end office, the reverse forwarding from the end station to the central office is effected in the following way. The passage cock at the central station is closed, and the cock F there is placed on "vacuum." The communication of the tubes B and R with the reservoir of rarefied air is thereby established, and with closed apparatus at the intermediate and end stations, an equilibrium on the whole line from the chief office to the end station will be produced between this reservoir and the conduit when cock F at the intermediate station remains placed on "passage."

For introducing the carrier boxes into the tube (Fig. 4) at the end office, the cock F there is closed, and also the door of the apparatus. Such a position is then given to the cock that the carriers, by means of the atmospheric air entering through tube S, are impelled to the next intermediate station, and there fall into the chamber, which, if only one intermediate station be existing on the line, is represented by Fig. 3. After the



PNEUMATIC DISPATCH IMPROVEMENTS.

there are the reservoirs of compressed air and of rarefied air, and from whence the carrier boxes are driven by compressed air to the intermediate and end stations. The transporting of the carriers back from these stations to the chief office is effected by means of rarefied air.

By this transformation of system, the efficiency of the establishment was raised very considerably, but at the same time also the cost of working, because of the more frequent dispatchings. Further, rarefied air, of which the production is expensive, is used in this system more extensively than in the polygonal system. But this latter inconvenience of the radial system is largely compensated by the greater efficiency of the establishment.

After the transformation of the net of conduits, endeavors were made to obtain also a simplification of the apparatus of receipt and delivery. The Felbinger apparatus first used proved to be very expensive, unwieldy in working, and requiring considerable space for their installation; consequently, as the branch stations were mostly located in hired premises, the expense was great.

The improved Felbinger apparatus, which has been used since 1886, is much simpler, an improvement which appears yet more distinctly in the pneumatic apparatus for intermediate stations with the so-called breech tube, modified according to the indications of Mr. Ehrke, secretary of superintendence of the chief post office at Berlin. These apparatus are described by Professor Rühlmann in the fourth volume of his "Allgemeine Maschinenlehre."

Lately Mr. Josef Wildemann, of 25 Kronprinzen Ufer, Berlin, has taken out a patent for a pneumatic receipt and delivery apparatus, which, by the simplicity of its arrangement and cheapness of cost, promises to be widely used. The Wildemann apparatus is exclusively employed in the pneumatic dispatch establishments of the Imperial German Post Office of Berlin.

is for producing equilibrium between the atmospheric air and the chamber.

Figs. 2 to 4 illustrate the manner of working of the apparatus. Fig. 2 shows the apparatus as used at the offices which are provided with air reservoirs, that is, at central stations or chief offices, while Fig. 4 shows an apparatus for stations having no air reservoirs, viz., for terminal stations. In the tubes between such stations there may be arranged places of interruption, or intermediate stations. At each such intermediate station an apparatus, as shown in Fig. 3, is intercalated.

In Fig. 2 both tubes A and B lead to the air reservoirs; tube A to the reservoir with compressed air and tube B from cock to the reservoir with rarefied air. At a suitable place on the conduit, but in the proximity of the apparatus, a common passage cock is intercalated which is opened when letters, etc., from this station or from the intermediate stations are to be dispatched to the end office, but which is closed when the transporting is to be effected in the inverse direction, that is to the central station and by means of rarefied air.

The letters, etc., to be dispatched from the central station are inclosed in leather boxes (carriers), which are put (Fig. 2) into the tube R, above the cock F, entering through the chamber; then, after the chamber door being closed, the cock F is placed on "compression," and the passage cock is opened. At the same time the attendant of the intermediate station, which by telegraph is advised of the departure of the dispatch box, places the cock F of his apparatus on "passage." The dispatch box thus will be driven by compressed air through conduit R to this intermediate station, and fall into the chamber of the apparatus there (Fig. 3). By placing the cock F to "passage," the air which is in the conduit before the dispatch box, and which must be dislodged, is now permitted to escape into the atmosphere through the channels and the tube S.

The sound of the dispatch box striking against the

arrival of the carrier box the attendant closes the cock F, so that the rarefied air now fills only the portion of the conduit from the chief office to the said cock.

Then the cock K on the chamber of the apparatus of the intermediate station is opened for producing equilibrium between the air in the chamber and the free air. Finally the door is opened, and the box, after the letters destined for this station have been taken out, is introduced into the tube. After closing the cock K and the door, and after turning the hand lever into the position "vacuum," the carrier box, in the same way as above described with regard to the dispatching from the end station, is, by the atmospheric air entering into tube S (Fig. 3), driven to the next branch station, or, as shown in the figures, to the central station. The carrier box is then taken out after closing cock F in the same way as at the intermediate station.

If the distances between the central station and the end offices are small, then, of course, the intermediate stations are dispensed with and the service will thus be simplified, as there then will be only the transport between the chief office and the end station, without intermediate stations.

Lately the carrying of the dispatches in the tubes has been effected in leather boxes having no metal lining and running at fixed periods from station to station. By this arrangement the officials know exactly at what time and in what direction they have to expect the arrival of the carrier. Including the delay at the stations for taking out and putting in the dispatches of the carrier boxes, the speed of the runs is so regulated that a distance of 1000 miles will be run through, forward or backward, in about 2½ minutes, so that every 2½ minutes a dispatching may be effected in any direction. If there is a greater distance between two neighboring offices, or if, in consequence of the greater length of the track, one or more intermediate offices are intercalated, the duration of the run will, of course, be longer. But it is claimed that by using the above described

apparatus, double the number of dispatchings, as compared with the old systems, may be effected during a given time.

The present apparatus have the advantage of simplification and more speedy transport of the dispatch carriers, in consequence of this simplification, which also causes reduced cost, both in the first instance and for repairs.—*Engineering.*

THE PELTON WHEEL WITH MULTIPLE NOZZLE.

THE cut represents the Pelton system of multiple nozzle wheels, by which large power is developed from comparatively low heads, and by which also increased speed can be secured when desired, for running dynamos or other high speed machinery. The cut shows only four streams, but the number can be increased to six or more, the power being multiplied in this way, according to number and size of nozzles, both nozzles and buckets being proportioned to power requirements and water available.

All the streams having a separate and distinct line

should be located nearly equidistant from roads on either side of the proposed location. In general, the road should be so located as to make the most direct and easy communication with a line of railroad or some prominent city or town, in order that the products of the farm, garden, etc., can be quickly put on the market.

The grades should be made as easy as possible, not to exceed seven feet in a hundred, except in very special cases, and for short distances, and not less than eight inches in a hundred. Excessive excavations and embankments should also be avoided, for as a general rule they tend to depreciate property on either side and present an unsightly appearance. The full width of the road should not be less than forty nor more than sixty feet; but the paved portion need be only from eighteen to twenty-four feet—eighteen feet being ample for the majority of country roads.

(2) *Preparing the Roadbed.*—When the location and width have been decided upon, accurate profile and cross section plans should be made and the grade established. The drainage area on each side, for at least a mile, should also be studied, in order to provide ample culverts,

may be used for the transverse connections, and may be laid flush with or a few inches above subgrade. Where gravel can be reached at a reasonable depth, all the above pipes can be omitted by merely building the basins down to gravel and leaving the bottom open. In this case they should be larger, and not over two hundred feet apart.

Provision should be made to carry off quickly any water that might pass through the pavement to the subgrade of the roadbed. This can be done either by making connections with the basins, or, even where the road is slightly in embankment, by laying tile or French drains from the subgrade at the sides, through the shoulders or wings. These drains are particularly useful during construction and while the drive is green. They should always be put in at the low points of grade and elsewhere, as may be found necessary. Bridges and culverts should be built where necessary, and their construction, dimensions, etc., made to suit the locality, the drainage area, etc. One of the most important features, in either bridges or culverts, is the foundation. When rock or hard clay cannot be reached, or where quicksands are found, a good, durable and inexpensive bed for the masonry can be made with one and a half or two-inch hemlock plank laid in double courses, the lower one placed lengthwise with the wall and the planks of full length, fourteen to sixteen feet; the top course should be at right angles to the lower one, and cut in such lengths as the thickness of the wall requires. This timber bed should extend two or three inches beyond the face, back and ends of the wall. It is entirely practical for moderately heavy walls, if there is a certainty of its being always covered with water. Where the drainage area is not very large, terra cotta pipe may take the place of a culvert; but it is less durable, and its use is poor economy.

(3) *Laying the Pavement.*—The two methods in general use for making road pavements are the Telford and Macadam. They differ chiefly in the character of the foundation or bottom course.

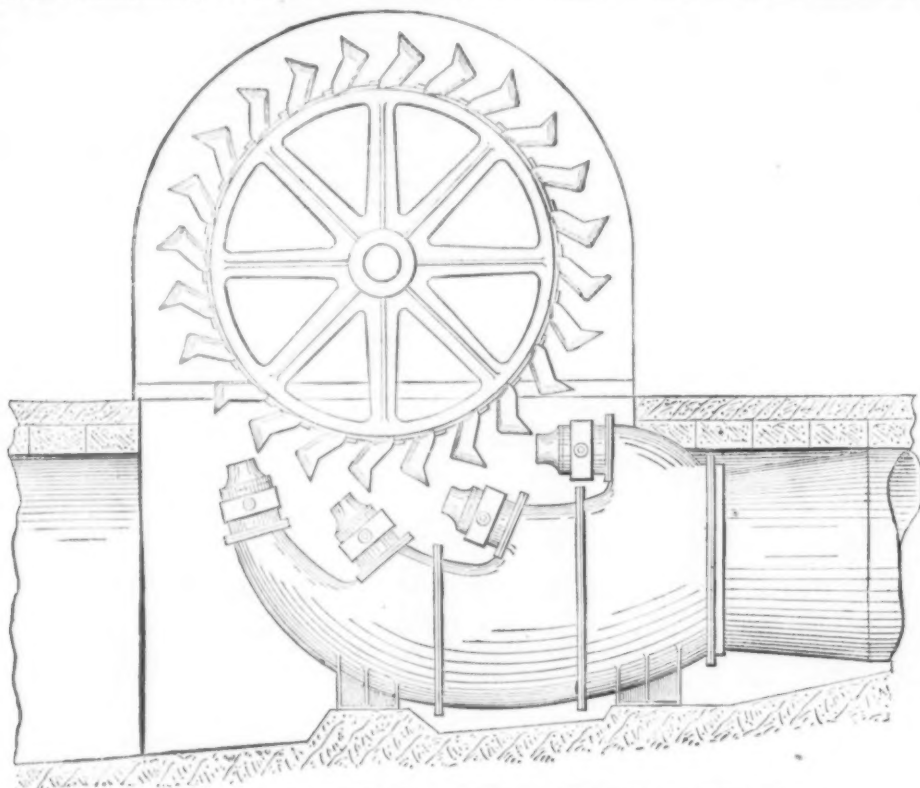
(a) TELFORD.

The construction of the Telford pavement may be divided into three parts: (1) Foundation; (2) broken stone covering; (3) top dressing.

(1) *Foundation.*—The foundation should be composed of irregularly shaped, hard, tough and durable stones, from eight to twelve inches long, four to six inches wide, and eight to twelve inches deep, according to the depth of the pavement, being as nearly as possible of the same depth for a given depth of pavement. These stones should be carefully placed by hand lengthwise across the road, their broadest edges down and breaking joints as far as possible. All irregularities of the upper part of said foundation should be broken off with a napping hammer, and the interstices filled with stone chips, thus making a smooth, firm and even pavement.

(2) *Covering.*—Upon the foundation thus prepared a layer of broken stone from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in size, according to its hardness, should be evenly spread to the depth of 4 inches, and thoroughly and repeatedly rolled with a roller weighing at least $2\frac{1}{2}$ tons. The stone for this covering should be the very best obtainable as regards hardness, toughness and power to resist abrasion and the action of the weather, for upon it will come the wear and tear of travel. For this purpose any of the trap rocks, granite or rock of a like character will be found to give entire satisfaction; and, although costing more at first, will be found much cheaper in the end than some of the softer stones. Practical experience and exhaustive tests have proved this beyond any doubt. A very light coat of clay upon this covering will be found advantageous in binding it to the top dressing, and should be applied during the rolling.

(3) *Top Dressing.*—A light top dressing of stone screenings should be evenly spread over the broken stone covering, well sprinkled and thoroughly and repeatedly rolled with a steam roller weighing from 15 to 25 tons. The sprinkling should be kept up during the rolling, and the rolling continued until the surface becomes perfectly hard and smooth. The rolling should begin at the sides and be continued toward the center, up one side and down the other, so as to keep the crown well up. Where the road is in embankment it is important that the shoulders or wings on each side of the pavement should be well formed and thor-



THE PELTON WHEEL WITH MULTIPLE NOZZLE.

of impingement do not conflict, and there is, therefore, no appreciable loss of efficiency. By this means, adaptation can be made to almost any requirement as to power, under heads ranging from 25 feet upward, affording all the advantages of simplicity, efficiency and small cost of maintenance that applies to the Pelton system under higher heads. Each nozzle has an independent gate valve to facilitate regulation and adapt the wheel to varying supplies of water. Where automatic regulation is desired, the valves, by suitable connections, can be all controlled by one governor.

Wheels of this character have been designed for the great Niagara Falls plant of capacity of 5,000 horse power each, running under 140 feet head, discharging 24,000 cubic feet of water per minute, which plans were awarded the prize by the London International Commission against all American competitors. This principle illustrates the remarkable flexibility of the Pelton system of power as well as its facility of adaptation to all conditions of volume, speed and pressure.—*Min. and Sci. Press.*

ROADS.*

By THOMAS G. JANVIER.

In considering the different features of the road question, it would be impossible to give rules or a set of specifications and directions to govern every case. In place of this a general form could be given, to be used as a guide, which, with some modifications, could be made to suit any particular locality.

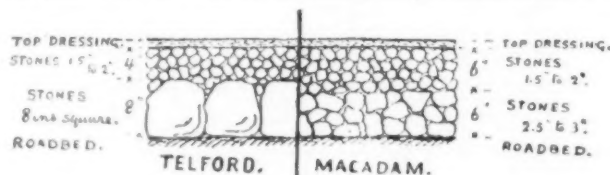
ENGINEERING FEATURES.

This branch of the road question may be divided into three parts: (1) Location; (2) preparing the roadbed; (3) laying the pavement.

(1) *Location.*—There are many points to be considered in locating a new road, and a few of the more important ones only will be noticed. First, the item of expense should be considered. In this connection, the grading, land damages, etc., should not be overlooked. If it is intended to connect two cities or large towns, the line should be as direct as possible, remembering that a slight deflection to the right or left, or an easy curve, might save considerable expense in the matter of excavation, embankment or bridging.

If lying near to and intended to make communication with some railroad, it should, if possible, be either parallel with or at right angles to the same. If parallel with a railroad, the distance from it should be determined largely by the position of other roads running in the same direction. It should also be located so as to accommodate the greatest number of people living in the vicinity through which it is proposed to run. If the proposed road is at right angles to a railroad, it

drains, etc. The roadbed should be carefully brought to subgrade, one foot, more or less, as may be required below finished grade. The longitudinal section must be of the same shape as the finished pavement, and the transverse or cross section also, in order to afford better drainage, so that any water which might get through the pavement may pass off quickly from the center of the roadbed. If the cross section of the subgrade is level or without any crown, then the crown must be made up in the pavement. This method will be found more expensive, more tedious and less satisfactory than that of making the crown in the subgrade. While the minimum grade could be eight inches per hundred feet, one foot would be much better, for unless the side gutters are very carefully and accurately graded and kept clean, it will be impossible for the water to run



off freely and quickly where the grade is so light; and this is a very important feature. The writer has built a road with a grade of only three inches in a hundred feet, and although the water was carried off, he would not recommend it, unless the gutters could be paved with asphalt blocks or something equally smooth.

The crown of the road from the center to the sides should not be less than half an inch, or more than three quarters of an inch, to the foot; less than the former would not give good drainage, and more than the latter would have a tendency to give a lateral or sliding motion to vehicles, and thus injure the finished surface.

Where the road passes through a wet or springy soil, the latter should be carefully drained by means of suitable terra cotta, tile or French drains. Drains laid in the shape of an inverted V, with the apex of the V pointing up the drive and located in the center, with its arms extending to the side ditches, basins or other outlets, will give very satisfactory results. Where a road is entirely in excavation for a distance of twelve hundred feet or more, and there is no way of getting rid of the surface water, this can be advantageously done by having brick or stone silt basins with top grating and back inlet stone built at each side of the drive, about four hundred feet apart. These basins should be connected transversely, and on one side of the drive, longitudinally, by terra cotta pipe laid not less than fifteen inches below subgrade. Iron pipe

ought to be used for the transverse connections, and may be laid flush with or a few inches above subgrade. When the finances will permit, rubble or cobble gutters from two to three feet wide should be laid on each side of the pavement. This will facilitate the surface drainage and prevent the washing away of the wings.

(b) MACADAM.

The roadbed or a subgrade for a Macadam pavement should be prepared in the same manner as for the Telford, but there is no foundation of squared stones, as there is in the Telford. Upon the roadbed or subgrade a layer of broken stone from $2\frac{1}{2}$ to 3 inches in size is evenly spread to the depth of 6 inches; this is covered with a 6 inch layer of stones from $1\frac{1}{2}$ to 2 inches in size, and the whole thoroughly rolled; then a light coat of clay is applied, and this is covered with stone screenings, sprinkled and thoroughly rolled, as before described.

There is much difference of opinion as to which of these two methods is the best for a general road pavement; but there should not be to any one who has watched the results of heavy travel upon Telford and Macadam pavements when laid on similar soil and under similar conditions. It will be found that ruts form sooner in the Macadam than in the Telford pavement, especially in the spring of the year. One reason for this is that the large foundation stones of the Telford present a greater surface of resistance to compression

* A paper read before the Engineers' Club of Philadelphia, 1891. From the Proceedings.

into the soil of the subgrade. The Macadam pavement is excellent for light travel, but is not equal to the Telford for general traffic.

A much cheaper road than either of the above can be made by using the Telford foundation and covering it with about four inches of gravel, containing sufficient clay to make it pack well. This makes a hard and smooth surface, is easily kept in repair, and is an excellent road for light travel.

A good road for eight months of the year can be made by placing about four inches of gravel upon the soil of the subgrade mentioned herein. Both of these gravel roads require rolling, shaping, etc.

COST OF THE ABOVE PAVEMENTS.

It is impossible to give the actual cost of any road improvement until a survey has been made, but an approximate estimate can be given from a careful preliminary observation.

The cost of earth excavation will be from 16 to 30 cents per cubic yard, according to the nature of the soil, the length of haul and the depth of cut.

Rock excavation costs from 50 to 75 cents per cubic yard. The stones suitable for a Telford foundation can be quarried and delivered on the work, provided a quarry is conveniently near, for \$1 per cubic yard; or, for an 8 in. foundation, allowing for waste, about 22 cents per square yard. Four good pavers can readily place 300 lineal feet of foundation, 18 ft. wide, in a day; and these at \$1.25 per day, and a foreman at \$2, will bring the cost of laying the foundation to 2½ cents per square yard. Broken stone from the same quarry can be delivered for \$1.25 per cubic yard, or about 14 cents per square yard, 4 in. deep. The minimum cost per square yard of a Telford pavement is about as follows:

Quarrying, delivering and placing foundation stones, broken stone covering, screening, sprinkling, rolling, etc.,	25 cts. per sq. yard
	$\frac{14}{9}$ " "
Total cost of a square yard of Telford pavement under the most favorable conditions,	46 cts.

Under other conditions the cost per square yard may reach 95 cents. The latter figure allows for the very

dry weather it should be sprinkled several times a day. This prevents the top dressing from blowing away and helps to keep the pavement firm and solid; for if it becomes very dry, it will soon bake, become loose and disintegrate. Too much water put on at one time has tendency to soften and loosen the pavement. If possible, ruts should never be permitted to form, but this can be prevented only by constant attention. As soon as there is an indication of a rut the loose detritus from the adjacent parts of the road should be raked or swept into it; this will soon become well packed by the travel. If a rut forms, a horse will naturally follow it, and it becomes worse and worse. If a rut has formed it should be filled at once flush with the pavement with 1 or 1½ in. stones, as may be required. When the general surface requires patching, it should be done in small pieces, in order that the travel may not be driven away from the repairs, and that wagons will drive over and pack them at once. The best time to make such repairs is immediately after a rain, as they will then pack much better. If made in dry weather, a sprinkler should be used. The frequent use of a 2½ ton roller is invaluable for keeping a road in good shape and condition. For the purpose of making these repairs, 1½ in. stones and screenings should be kept on hand at several points along the drive.

It is also important that the side ditches or gutters and all drains and inlets should be kept open and in good shape, so that the surface water may run off quickly. It is also important that all dirt roads intersecting a paved road should be paved for a distance of two or three hundred feet from the intersection, in order that as little mud as possible shall be carried on to the paved road.

The following are important points to be observed in the maintenance of a road :

1. All sand and dirt must be removed as frequently as possible.
2. The entire drainage system must be carefully maintained.
3. Constant and daily repairs and patches wherever and whenever ruts or depressions begin to show.
4. Careful sprinkling at least three or four times a day in dry weather.

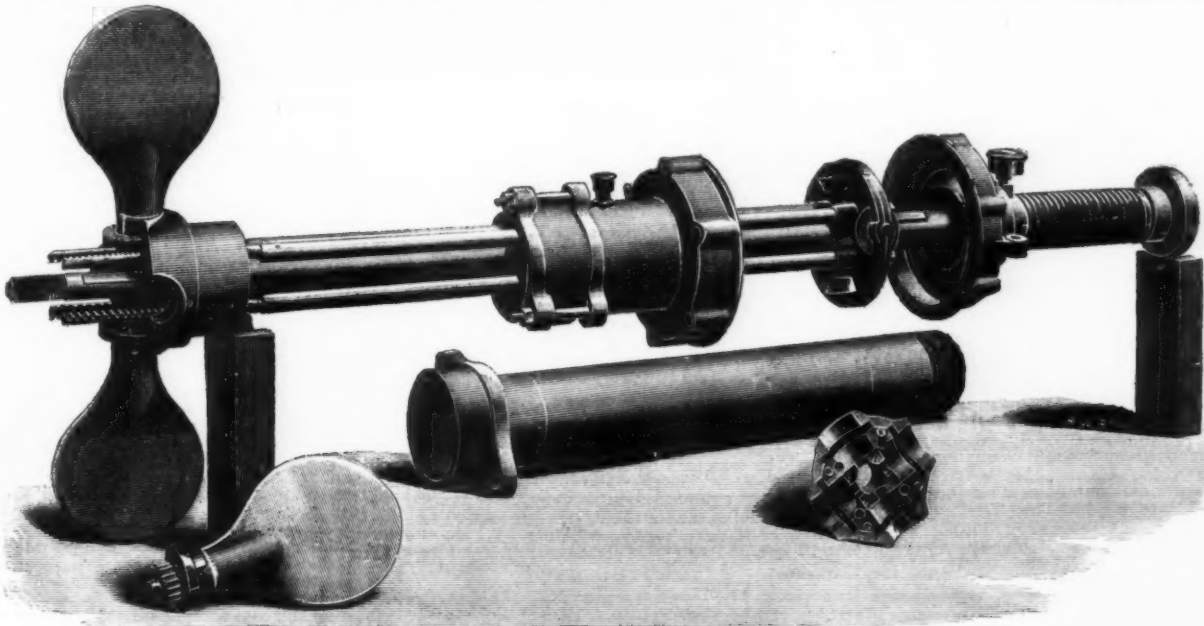
drainage system in good condition. During the summer months he should keep the road properly sprinkled and make such repairs as may be necessary.

NEEDED REFORMS IN LEGISLATION.

- (1) Abolish the present system of working out road taxes, and have them paid in cash.
- (2) Each county should have a superintendent of roads, who should be either appointed or elected for a term of years and well paid for his services. Each township should have a supervisor, subject to and under the direction of the county superintendent.
- (3) The road taxes for each township should be expended by the supervisor, who should be held accountable to the township board or other authorities for the wise, judicious and honest expenditure of all moneys placed in his hands. He should employ labor to the best advantage, but, other things being equal, preference should be given to home labor. He should file a proper bond for the faithful performance of all duties. He shall build such new roads, bridges, etc., as the township board may direct, and properly maintain the old roads.
- (4) There should be a standard set of specifications for the construction of all the roads of the State, subject to such modifications as may be found necessary for special localities, counties or townships.
- (5) The State should build two roads at right angles or nearly so, and as nearly through the center of the State as may be practicable. Each county should do the same. This would offer great inducements for the townships to build the shorter roads.
- (6) The State should offer a yearly prize to the county having throughout the year the best ten or fifteen miles of road, and each county a prize to the township having the best mile or two.

THE ADVANTAGES TO BE DERIVED FROM IMPROVED ROADS.

- (1) It has been found by practical and thorough tests that the motive power of a horse on a good stone road is at least double what it is on a dirt road in good condition. What would be the proportion with the dirt road in bad condition, full of ruts, etc.?



THE MARQUE SCREW PROPELLER.

best stones, transported by cars and then hauled. To these figures must be added the cost of grading, draining, bridging, etc.

There is comparatively little difference between the cost of a Telford and that of a Macadam road of the same depth. A road made by putting four inches of gravel on a Telford foundation will cost about 35 cents per square yard, exclusive of grading, etc.

A gravel road on the natural soil of the subgrade can be made for about 10 cents per square yard, exclusive of grading, etc.

RECONSTRUCTION.

A Telford or Macadam road, thoroughly constructed and properly maintained, will never require reconstruction; but there are roads, such as some of our old pikes, having from eight to ten ruts their entire length, said ruts being from two to four inches wide and three to six inches deep, which need it badly.

The best method for the reconstruction of such a road, when there is much of a deposit of mud and dirt, is: First to remove this deposit, then place upon the broken stone, four inches deep at the sides and six inches at the center, thus giving a crown of four inches. These stones should be put on in two layers, the lower one consisting of stones from two to two and one-half inches in size, and the upper one from one and one-half to two inches, according to their hardness; screenings should then be put on, sprinkled, rolled, etc., as in the Telford pavement. Where a change of grade may be found desirable, it is best to put down the Telford pavement after such a portion has been properly brought to subgrade. The drainage system should also be improved where necessary.

The cost of such reconstruction, exclusive of the Telford portions and drainage, will be from thirty to forty-five cents per square yard, depending upon the cost of the broken stone delivered along the road.

MAINTENANCE.

The best system for maintaining a Telford or Macadam road for ordinary travel is that of constant daily attention and repairs. All mud and dirt should be removed, so as to expose the surface of the pavement. In

5. The frequent use of a 2½ ton roller.

Gillmore gives the following results of daily repairs made upon a road of ordinary or moderate travel, as ascertained after exhaustive tests by French engineers: "It was found that in proportion as the interval between the periods of repairs was shortened upon such roads (about 600 tons being the daily tonnage of travel), the annual expense was lessened; and the roads were always in better condition; and finally that the roads were never so good or the expense of maintenance so small as when the system of unremitting and minute attention was in full operation. . . . The road from Tours to Caen, which had been the subject of occasional repairs from 1832 to 1836, at an annual cost of \$378 for material and labor, was in such a bad condition that it required four horses to draw the mail coach, and the service was so severe on the horses that eleven died from overwork during the year. In 1838, when the system of constant and minute repairs was in full operation, only two horses were necessary to draw the same coach. Under this system, from 1837 to 1841, the annual cost for material and labor was \$280, thus showing, under the new system, a saving of 12 per cent. per annum in the expenses and maintenance and 250 per cent. in the amount of animal power required for a special item of traffic."

A road of very heavy traffic may require resurfacing to the depth of three or four inches every five or six years, and when the length of the road is fifteen or twenty miles, it is better to resurface two or three miles every year. This resurfacing should be done in the same way as the finishing of a Telford pavement. As far as possible it should be done in the spring or fall, so as to have the advantage of the rainy season. The cost of such resurfacing will be from 20 to 35 cents per square yard, according to the quality of the stone used and the facilities for obtaining it.

One man, with a pair of horses, sprinkling wagon, roller, cart, etc., should be able to keep in good repair at least three to four miles of Telford road. During the spring, fall and winter months he should put on such new material as may be found necessary and keep the ditches or gutters cleaned out and the

- (2) One horse can easily haul one ton at the rate of six miles an hour, on a level Telford road, in summer or in winter. How fast could he haul the same load over a dirt road in muddy weather, or when the frost is coming out of the ground? In other words, the farmer with two horses could haul over a good stone road as much grain, marketing, etc., as he could with four horses over a dirt road and in half the time, thus showing an immense saving both in animal power and in time.

(3) A good stone road will always be an inducement for men of business and others from the city, desiring country homes, to locate on the line of the same. These would bring others who would erect desirable dwellings, and thus enhance the value of adjoining land; thus increasing the amount of travel and decreasing the per capita for road maintenance; bringing the consumers of all farm products to the farmers' doors. In a short time other roads would have to be opened, and old ones improved, and it would not be long before the entire section would insist upon and have the very best stone roads.

THE MARQUE SCREW PROPELLER.

THE above engraving shows clearly the mechanical details of the design of the Marque feathering propeller. A solid collar is formed on the base of each propeller blade, and below this again is a toothed pinion; the propeller boss, within which are suitable recesses, with bearing surfaces for the collars, is made in halves and bolted together by longitudinal bolts in the usual way; the outer end of the propeller boss, not shown in the engraving, is of spherical form. Each blade is actuated by a rod supported in guides or bearings where necessary, and terminating in a toothed rack, which gears with the pinions on the base of the blades. The rods are connected to a disk, revolving between guide or thrust plates, which are bolted together as indicated in the engraving, and by moving them forward or backward, the straight rods, by the racks at the end of them, actuate the propeller blades, causing them to

rotate and assume any desired angle with the center line of the propeller shaft.

In the example selected for illustration, the necessary movement is imparted to the guide or thrust plates, by causing them to rotate along a short length of a square-threaded screw, formed on a portion of the propeller shaft, by suitable gearing, or by an endless pitch chain, which is worked either by hand or by a steam steering gear according to the size of the vessel. To meet special cases the feathering gear can, however, be actuated without interfering in any way with the stern tube or shafting, although naturally a direct thrust from the guide plates is to be preferred.

The propeller illustrated is of small dimensions, and the details are, of course, varied somewhat to suit large vessels, the principle, however, remaining the same; the blades are generally built up of steel or phosphor-bronze sheets, on a strong cast steel frame, and are in relative proportion longer and narrower than those shown in the engraving. Means are also provided of automatically varying the steam supply to suit the angle of the blades, so as to prevent the engines racing when the pitch of the blades is reduced beyond a given point, and by a small worm wheel and gear, not shown in the engraving, the exact angle assumed by the blades is indicated on a dial at any part of the vessel.

It will be noted that the propeller blades, being entirely independent of one another, no strain is thrown on the feathering gear if one or more of them should be carried away.

Several steam launches and small yachts have been fitted with the propellers, and have now been running some time, and it is stated with satisfactory results; one of them is, we hear, now in the Thames for trial, and an extended series of trial runs with another vessel on the Scheldt has been made by the officials of the French and Belgian governments. Other trials made by the French government engineers on the Seine have led them to fit a propeller, at their own expense, to one of the dockyard tugs, indicating about 500 horse power, which is now nearly ready for service.

The Perfect Feathering Propeller Syndicate, of London, E. C., are introducing the invention.—*Engineering*.

SIBLEY COLLEGE LECTURES.—1891-92.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

H.—CENTRIFUGAL FORCE AND RESULTING PHENOMENA.

By CHARLES E. EMERY, Ph.D., of New York.

THE comparative frequency of accidents to the fly wheels of steam engines during recent years has impressed the speaker with the desirability of an investigation of the general subject of centrifugal force, particularly the limitations which it imposes on the design of pulleys, fly wheels and other machinery, and the influence it will have in the near future on the speed of railway trains. It is proposed to illustrate the destructive effects due to centrifugal force by photographic representations of machinery and buildings injured in this way, and finally to state in general terms some features developed during recent litigation on the subject, which it is thought will be of interest to students of mechanical and electrical engineering.

The recent fly wheel accidents appear to be due either to defects in material or to the centrifugal force developed by the running away of the engines rather than to the comparatively high speeds at which engines are now being operated, or to the higher strains on material now found desirable under the spur of competition to produce increased work in engines of a given size by the use of higher steam pressures. It does not appear that fly wheels of customary construction should be unsafe at the comparatively high speeds now in common use, if proper materials were always used in construction.

The weight of evidence is that the factor of safety of fly wheels operated at the low speeds formerly in vogue was so high that fly wheel disruptions were very infrequent, and that therefore no special care was taken to secure superior designs, materials and workmanship. It is a curious fact, also, that all the hand books, as well as most of the text books, the writer has consulted either fail to point out the manner in which the formula for centrifugal force should be applied, in calculating the ultimate strength of a fly wheel to resist centrifugal force, or actually make such misapplication of the rule that the resulting disrupting force shown is over $4\frac{1}{2}$ times as great as it should be; so it is believed that designs have frequently been based on the performances of other wheels, rather than the formulae in the books. Some of the more elaborate works on applied mechanics and the recent and most excellent work of Prof. Thurston on the steam engine, however, contain a full discussion of the subject, with resulting formulae, which correspond, by changing the notation, to those hereinafter deduced without the aid of the calculus on the principle of fluid pressure. All the rules agree as to the value of the centrifugal force due to swinging a single weight around a center, as in slinging a stone, and all will show the same strain on the string of the sling. The centrifugal force in this case is, as is well known, equal to the weight multiplied by the square of the velocity of such weight in its circular path in feet per second and divided by 32.16 times the length of the string or the radius of the circle. 32.16 is the value of the acceleratrix of gravity, usually designated by g , for the latitude of 42° ; 32.2 being more nearly accurate for the latitude of London. In designing fly wheels it is customary to consider that the rim is of itself sufficiently strong to resist disruption from centrifugal force without assistance from the arms. The desirability of doing this will be discussed later. The error introduced in many of the hand books arises from calculating the centrifugal force from the weight of the entire rim by the rule above given; whereas it is evident that only the weight of one-half the rim pulls against that of the other half to produce disruption along any particular diameter. So the result should be divided by two; and again the centrifugal force produced by each half rim is resisted by double the sectional area of the rim, or by the sections at the two ends of the diameter. So the result should be again divided by two, or by four in all, to find the unit strain on this basis. This result is still, however, 57 per cent. too large, for the

reason that all the elementary weights in a half ring do not act at right angles to any diameter to produce rupture, but each pulls radially outward. So the resulting strain is exactly the same as that arising from fluid pressure within the shell of a steam boiler. In the latter case the strain on the double thickness of shell is, as well known, equal to the pressure on one inch of width multiplied by the diameter in inches. So if we consider the rim of a fly wheel or any pulley as a series of segments connected together at their edges, each say one inch wide at the outer end of radius of gyration, the total disruptive force at any diameter is equal to the sum of the components of the centrifugal forces produced by all the segments in a semicircumference, or to the centrifugal force produced by one segment multiplied by the diameter, and not by the semicircumference. The disrupting force thus obtained is resisted by two thicknesses of metal. So the result must be divided by double the section of the rim in square inches in order to obtain the unit strain on the material. In a fly wheel or pulley rim, however, the section which causes the weight is also the section which resists disruption. The width of the rim makes no difference, as each inch of width increases the weight and also increases the section. This is also true of the thickness, except that increase of thickness slightly increases the effective diameter. It therefore follows that the force which will disrupt a fly wheel is independent of the actual weight, width or thickness of section, and only varies with the tensile strength of the material, the unit weight of the same and the square of the velocity.

FORMULA FOR CENTRIFUGAL FORCE APPLIED TO FLY WHEELS, ETC.

W = weight considered in pounds.
 W_1 = weight of segment of rim one inch thick, in pounds.
 Q = centrifugal force, in pounds.
 Q_1 = centrifugal force of segment one inch thick, in pounds.
 S = strain per square inch of section in general, in pounds.
 S_1 = strain per square foot of section, in pounds.
 S_2 = strain per square inch of section of cast iron, in pounds.
 S_3 = strain per square inch of section of wrought iron, in pounds.
 S_4 = strain per square inch of section of steel, in pounds.
 A = area of rim section in square feet.
 v = velocity in feet per second.
 V = velocity in feet per minute.
 r = radius of gyration in feet.
 G = weight of metal per cubic foot.
 F = disrupting force in pounds.
 g = 32.16 = acceleratrix of gravity, in pounds.

$$(1) \quad Q = \frac{Wv^2}{gr}$$

$$(2) \quad W_1 = \frac{GA}{12}$$

$$(3) \quad v^2 = \frac{V^2}{3600}$$

$$(4) \quad S_1 = 144 S$$

$$(5) \quad F = 2 AS_1 = 2r \times 12 Q_1 = \frac{2r \times 12 W_1 v^2}{gr}$$

$$(6) \quad S = 0.0000006 GV^2 = \frac{6 GV^2}{10^6}$$

$$(6a) \quad S_1 = \frac{Gv^2}{g}$$

For cast iron, $G = 450$, so

$$(7) \quad S_1 = 0.000027 V^2 = \frac{27 V^2}{10^6}$$

$$(8) \quad V = 192.5 \sqrt{S_1}$$

$$(8a) \quad v = \sqrt{\frac{g}{G} S_1}$$

Referring to the notation and formulae now shown on the screen, Eq. (1) will be recognized as the general formula for centrifugal force. The velocity, it will be understood, is that due to a diameter equal to the double radius of gyration of the section, or for approximate work to the external diameter of pulley less the average thickness of rim. By Eq. (2) the weight of a segment or radial slice one inch thick at end of radius of gyration equals the volume, or one-twelfth of the area in square feet multiplied by the weight of one square foot. By Eq. (5) the disrupting force, F , is made equal to twice the section, A , of rim multiplied by the tensile strength, S_1 , of material, which result equals twice the radius, r , or the diameter, multiplied by 12 to reduce to inches, into the centrifugal force, Q_1 , due to a single segment, on principles above explained. The value of Q is substituted in the last member from Eq. (1), writing W_1 for W . By combining with Eqs. (3) and (4) we easily obtain Eq. (6), and substituting in the weight $G = 450$ of a cubic foot of cast iron, we observe from Eq. (7) that the tensile strain, S_1 , per square inch of section of a cast iron rim may be found by multiplying the square of the velocity of the rim in feet per minute by 27, and pointing off six places of decimals. Eq. (8) is evidently derived from Eq. (7). Wrought iron and steel are a little heavier than cast iron, which may be considered by substituting S_2 or S_3 for S_1 in Eq. (7) and multiplying the second number by 1.067 in the first case and 1.088 in the second case. In Eqs. (6) or (7), by making S or S_2 equal to the ultimate tensile strength of the material, the value of V will represent the velocity at which the rim should be disrupted. While good gun iron has a tensile strength of 40,000 pounds per square inch and upward, and ordinary castings generally have a tensile strength of 15,000 pounds, it is thought best to consider the ultimate tensile strength of cast iron pulleys as 10,000 pounds per square inch, for the reason that pulleys cast in one piece are subject to internal strains,

and even fly wheels and pulleys built up of pieces are liable to have blow holes in some part, and generally also the fastenings are not equal in strength to the solid rim. On the basis of 10,000 lb. tensile strength, the rim of a cast iron wheel should, according to Eq. (7), be disrupted when its velocity has reached 19,235 feet or 3.64 miles per minute. Ordinarily, the rim velocity of fly wheels is less than a mile a minute, but in some cases it is higher. With 6,083 feet, or 1.15 miles per minute, the strain on rim is only 1,000 pounds per square inch of section. Evidently, if this is practically the limiting strain used for a cast iron fly wheel rim, it should not be exceeded on a cast iron car wheel, the better material used being required to offset the effect of jars and internal strains due to chilling the faces. Cast iron car wheels should not, therefore, be run at a high speed than 1.15 miles per minute, or 69 miles per hour. The factor of safety at this speed for both the fly wheel and car wheel would be 10 to 15 for 10,000 to 15,000 pounds tensile strength. The same factor of safety for a wrought iron or steel rim would permit a unit strain of 5,000 pounds per square inch, and a rim speed of 201 miles per hour. So the dreams of the electrical engineers need not be disturbed by fears of the influence of centrifugal force, at least if kept within the limits of doubling or even more than trebling the present speeds of railroad trains.

Returning to the effect of the arms of a wheel on the result, it should be borne in mind that they are also influenced by centrifugal force, which increases with the weight required to increase their strength. If it be considered that the outer attachments of arm to rim of a built-up fly wheel are such that the center of gravity of the arm is at half its length from center of shaft to rim of pulley, the unit strain will be exactly half that shown in equations (6) and (7) for the rim, so by calculation half the strength is available to strengthen the rim, or a trifle more if the fly wheel centers are relatively large. The arms, however, are subject to transverse strains, if not from belts, at least from changes of speed, and there is, moreover, no certainty that the arms and rim will be adjusted so as to pull exactly together in resisting disruption. So the plan of considering the rim by itself and making it strong enough to resist disruption by centrifugal force within safe limits, as is assumed in the calculations above, is altogether the safer way.

The destructive energy developed by the disruption of a large fly wheel will first be illustrated by lantern slides made from a very complete set of photographs of the ruins resulting from the destruction of a large fly wheel in the Amoskeag Mills, at Manchester, N. H., which took place on the 15th of October, 1891, the photographs being kindly furnished by Past Assistant Engineer Charles H. Manning, U. S. N. (retired), the superintendent of the company. This company has a series of mills distributed along both sides of the Merrimack River for a distance of a mile and upward, the machinery of which is operated by water power during the season the same is available and by large engines at other times. Much of the time the engines are connected to part of the water wheels and supply any deficiency in the power of the latter. The engineering features are on a large and interesting scale. For instance, a large boiler house is located on the west bank of the river, from which steam is conducted through a pipe laid across the river on a special bridge to engines on the east side, and the exhaust brought back through another pipe on another bridge. The engine to which the accident occurred was of the double Corliss condensing type, with 36 inch cylinders, rated at about 2,000 horse power. The steam pressure was 95 pounds per square inch. The normal speed of engines was from 60 to 61 revolutions per minute, and they were furnishing just previous to the accident 1,900 to 1,950 horse power, independent of a light water power connected to the same shafting, which was considered, under the conditions, insufficient to materially increase the speed. The fly wheel was 30 feet in diameter and had something more than 9 ft. face. It carried three belts, one 24 in. wide running to the westward and connecting to a jack pulley on a shaft leading northerly to operate mills 7 and 8, the other belts each 42 in. wide, arranged on either side of the former, running to the eastward and connecting to two separate jack pulleys on a shaft leading southerly and operating mills Nos. 3 and 4. The first difficulty observed was the slowing of the speed of the looms in mills 3 and 4, due, according to some accounts, to some derangement of a tightening pulley on one of the 42 in. belts. The operatives, therefore, as per standing orders, stopped the machinery, which, according to the finding of the coroner's jury, relieved the engines of 1,500 horse power, which caused them to accelerate their speed, the governor not controlling them as promptly as was customary. This increased speed quickened that of the looms in mills 7 and 8, and all but one were automatically thrown off, thus relieving the engine of 300 horse power more and causing the speed to increase still more. The engineers quickly detected the increased speed and commenced closing the throttles, but when one was entirely closed and the other practically so, the fly wheel was suddenly disrupted, killing one of the engineers, wounding another and cutting a broad swath in the roof and walls of the engine room and those of an adjoining building to the westward, the basement of which was used as a pump room and the upper part as a drawing room, and causing the death in the latter room of two operatives. Let us approach these buildings from the outside, first looking at the west side of the pump and drawing in building in which the operatives were killed. The result of the accident was that a broad opening like a portal was cut through the wall of this building, as well as through the wall of the adjoining engine room. The large pipe at the foot of the break is the main exhaust pipe used for heating purposes, which may be utilized as a steam pipe from the boiler house across the river via the north bridge.

We now look from the outside at the east side of the engine room. Here the destruction is more complete. A broad opening is cut in the wall and roof, and we see that a portion of the latter on either side of the cut has tumbled in. We see in the background the top of the large opening previously observed in the west wall of the pump and drawing-in room.

We now step inside the engine house and look from a point considerably to the left of the engines, where

the opening through the west wall is not in sight, and view the wreck. On either side fragments of the roof still remaining in place are seen, and the ground is strewn with bricks, timber and material of all kinds. The large vertical pipes in the background belong to the Bulkley jet condenser, in which you will recollect the vacuum is produced by a tall water column instead of an air pump.*

The next view from the right of crank of right hand engine shows the fragments of the fly wheel in connection with the cranks, parts of the bed plates and the fallen roof in position.

were found in many of the same, and samples of the material varied in ultimate tensile strength from 15,000 down to 1,000 pounds per square inch, showing clearly that the wheel had been running for a number of years with a dangerously low margin of safety, and that it was finally disrupted under an increase of strain of trifling importance in comparison with its supposed ultimate strength, and under conditions very much less exacting than those occurring regularly many times in a day or even in an hour with engines of a similar kind subjected to variable loads.

We will now show on the screen two views of a



BURSTING OF FLY WHEEL—AMOSKEAG MILLS.

It has been previously stated that one loom in mills 7 and 8 did not stop. Careful tests were made with this loom to ascertain the speed at which the automatic stopping apparatus would operate, from which the coroner's jury decided that such loom could not at the time of the disruption of the fly wheel have been making more than 170 or 175 picks per minute, corresponding to 72 to 74 1/2 revolutions per minute of the engine. According to the rule previously given for a cast iron wheel 30 ft. outside diameter, or say roughly 20 1/2 ft., for the double radius of gyration, disruption should not have taken place at less than 205 1/2 revolutions per minute, even if the average tensile strength of the rim section was only 10,000 pounds per square inch. It is natural to suppose, therefore, that the wheel failed from defects in construction or material. The face was very wide for one set of arms, and therefore weak to resist lateral strain. There would have been some side strain if one only of the two 42 inch belts became slackened, but it would seem quite insufficient to cause the breakage. The disruption was, however, readily accounted for by defects in the castings. Very large blow holes

* This view and a plan and an elevation of the engine room are all the illustrations reproduced in this publication.

wreck caused by the disruption of the fly wheel of a compound Corliss condensing engine employed to operate a portion of the electric lighting machinery in the electric station of the Electric Light and Gas Company, of Lynn, Mass. The engine was provided with cylinders 20 in. and 36 in. in diameter each, with 48 in. stroke of piston, and connected to a crank at one end of the fly wheel shaft. The surface condenser was of the Wheeler independent form, with independent circulating and air pump, the station being near an arm of the sea. The fly wheel was 20 ft. in diameter, with 40 in. face, and was said to weigh 38,000 pounds. It was belted directly to a jack pulley on a shaft near the center of the building, a little way in front of the cylinders. The passage in front of the cylinders was under the slack side of the belt, and over the tight side, which ran underneath the floor at that point. The jack shaft was continued by several lengths of line shafting, connected by friction clutches, and carried pulleys belting directly to the dynamos. The accident occurred in October, 1890, in connection with a small fire in the tower of the building from which the conductors for arc lamps were carried out to the pole lines. The nature of the destruction was very similar to that

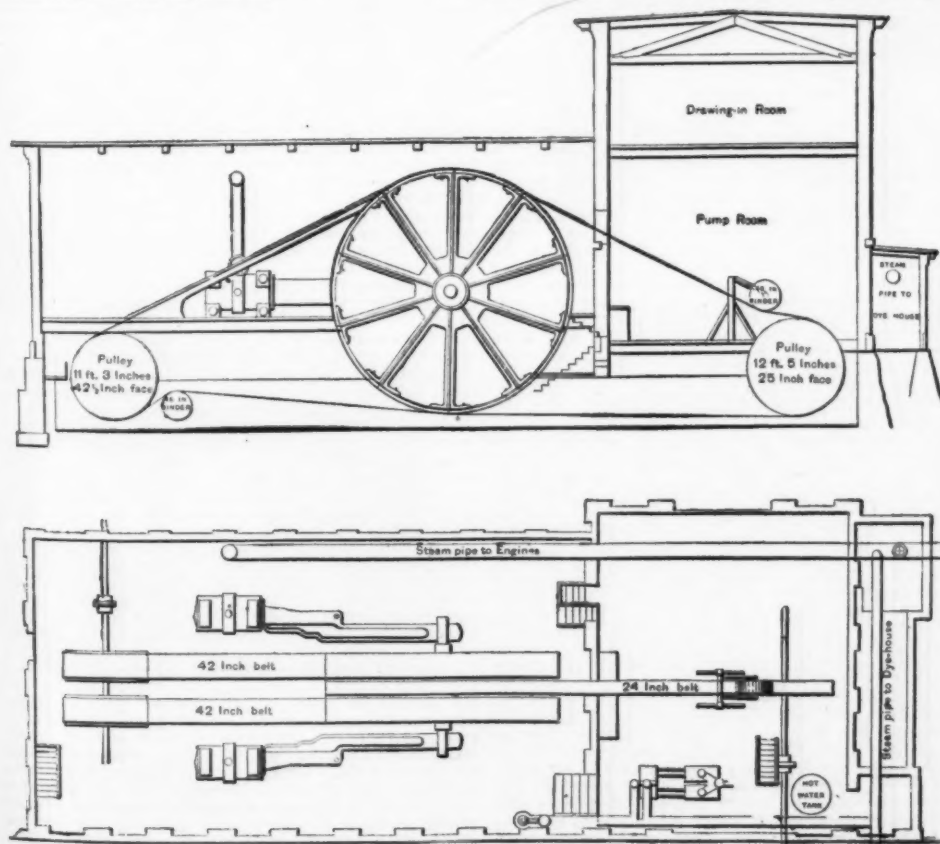
which occurred at Manchester, a swath being cut through the roof and both sides of the building, and at least one piece of the fly wheel was carried fully 150 ft. horizontally across a vacant lot and a railroad track, wrecking the corner of a house and falling alongside the cabin of the watchman at the railroad crossing. Fortunately, no deaths resulted from this accident, though two men were temporarily injured by flying pieces.

Interest in the case has been renewed by a suit brought by the electric company against the insurance companies for reimbursement for all the damages that occurred, not only from the fire directly, but those due to the wrecking of the engine. In connection with Mr. Manning, of the Amoskeag Mills, previously mentioned, and Mr. C. J. H. Woodbury, vice-president of the Boston Manufacturers' Mutual Fire Insurance Co., the speaker was engaged as an expert by the insurance companies. It is thought that it will be of interest to briefly state the points claimed by each side in this very interesting litigation, for the reason that all were dependent on electrical and mechanical engineering principles combined in an unusual way.

The insurance law in Massachusetts is understood to be that insurance companies are responsible, not only for the fire, but for all damage directly occasioned by the fire. The burden of proof is, however, on the insured to show that the losses other than those from the fire itself were actually occasioned by the fire. The plaintiffs in this case did not, therefore, attempt to account for the fire in the first instance, but endeavored to show that such fire caused all the damage, they claiming that the fire caused a short circuit in the tower by enveloping the plates of the fire arresters in flame and possibly expanding them so that they came in contact. They claimed that this short circuit was brought on so suddenly that it broke the pulley operating the dynamos then in use, that pieces of this pulley flew and hit others, and, according to one phase of the theory, one of the pieces broke off one ball of the governor so that the engine ran away and caused the damage; and, according to another phase, providing for the fact that the loss of one ball would not disable the governor, it was assumed that the jar due to breaking the first pulley caused the next pulley to break, and that the next, and so on, from pulley to pulley, across several undisturbed bearings and a friction clutch attachment, a distance of about 30 ft., until the jack pulley was thus broken, and that then pieces of this were carried by the belt under the fly wheel and broke that, causing the wreck.

On the part of the defendants it was only necessary to disprove the probability of the assumptions, but, in addition, affirmative proof was presented to show that the conditions indicated a defect in the governor belt and that the damage to the machinery was simply due to the running away of the engine. The disaster occurred between 1:30 and 2 A. M., when current was being supplied for only ninety-five arc lights and for incandescent lights in the station. The arc lights were operated by two fifty-light Thomson-Houston dynamos, such lights being distributed in four circuits from the station, which were, however, coupled two and two in series, so as to form one circuit for each machine. Both dynamos were operated by one pulley on the line shaft, the belt to the pulley of the farther dynamo running over the driving pulley on the top of the belt from the other dynamo. A similar pair of dynamos were running on open circuit at the time, and, in addition, an alternating dynamo and exciter for the same were in operation to light the station. There were at the time only two men in the engine and dynamo room and a third man in the fire room adjoining. The testimony of all was to the effect that one discovered the fire in the tower, and that another, who was busy wiping shafting, came and inspected it. The statements were to the effect that up to that time everything was working smoothly. It was stated that one called out to the fireman to blow the whistle, and then turned on the fire alarm near another entrance to the building, and that the watchman, after inspecting the fire, went to the throttle valve of the engine. It was claimed that suddenly there was a tremendous roar, indicating a short circuit. The evidence of the fireman would imply that the roar continued for some time, but the testimony of the engineer was to the effect that coincidentally therewith the pulley driving the two dynamos went to pieces, and that immediately other pulleys commenced to fly, and that he left the building. The watchman claimed that he had started to shut steam off the engine, for a reason not clearly explained, but that the pulleys commenced to fly, and he, though struck by a flying fragment, bounded over a gate out of another entrance.

All the experts agreed that the first effect of short-circuiting a Thomson-Houston arc dynamo is to materially increase the load, due to the increase of current, but that such load is very soon brought back to the normal by the action of the current regulator. The efforts of the plaintiffs were to show that the short circuit, being an electric phenomenon, brought an instantaneous shock on the dynamo, which was transmitted through the belts from the dynamos to the operating pulley on the main shaft. Instances were cited showing that a belt operating a dynamo had in several cases been run off in this way, and in one instance the belt became foul with the operating pulley in such a way as to crush it. An important point arose as to the time it required the dynamo regulator to act and reduce the current; several of the witnesses claiming that it required ten to fifteen seconds, and all agreeing that this time would vary with the condition of the apparatus, and the amount of damping afforded by the fluid in the cylinder attached to the regulator. As a method of accounting for the short circuiting, the plaintiffs presented a diagram of the lightning arresters in the tower. There was one connected in each outgoing and each incoming conductor of each circuit, and as there were four circuits in use there were, therefore, eight lightning arresters involved. The four circuits were, however, as stated, coupled up at the time to make two, one for each machine; that is, the current going out from one terminal of the dynamo came back to the switch board instead of to the dynamo and was directed out on another circuit and brought back to the dynamo through the second terminal of the second circuit. To account for the short circuiting it was claimed that the fire filled the whole tower with flame, which, as it contained carbon, was a conductor and short-circuited the dynamos by en-



PLAN AND ELEVATION OF ENGINE ROOM OF AMOSKEAG MILLS, MANCHESTER, N. H.

veloping the segments of the lightning arresters. It was also claimed that in due time such segments became sufficiently expanded by heat to be brought in actual contact, and thereby make a metallic short circuit. It was further claimed that fragments of carbon from the burning wood work dropped between the horns of lightning arresters and thus short-circuited them, and that in one or more of these several ways the several lightning arresters were connected to form a short circuit. In response, the defendants urged the improbability of any such action. Such a short circuit could only take place by grounding both branches of each circuit through two lightning arresters at the same time. The fire was localized in the vicinity of two of the arresters which were on the same circuit, but such circuit was connected in series with another, so that if short-circuited it would only cut out about half the lights in the double circuit, or one-fourth of the whole. Two other lightning arresters of the four circuits were near and two more were on the opposite side of the tower, where there were few signs of fire. It was clearly shown that to short-circuit all the lights through the lightning arresters the segments of at least four widely separated must be in contact or the space bridged by flame or dropping sparks at exactly the same instant, and if this were done by flame it was necessary that the flames, which would naturally roll around and show alternately flame and smoke as in any fire, should form forks of conducting flame sufficient to form a short circuit at four to eight different points in the tower at exactly the same instant. Any less mysterious coincidence would only short-circuit one pair of lightning arresters and cut out about half the lights on one dynamo, or roughly one-quarter of the whole, and if this operation were repeated shortly after, another quarter would follow, and so on, and instead of a sudden shock it would be a series of small shocks quite insufficient, even on the theory of the plaintiffs, to cause the damage. It was shown that the quadrants of the lightning arresters would be expanded at a temperature of 1,200 degrees sufficient to be brought in contact, but it was difficult to suppose that the flame was at a sufficiently high temperature to expand all at the same time when the fire was confined to one corner of the tower. Ordinary flame has a temperature, according to the books, of 790°, for the reason that currents of air are commingled with it in order to carry on the combustion with a material developing so much hydrocarbon gas in the process of combustion. Brass melts at about 1,950°, and it is well known that brass cannot be melted in an ordinary wood fire, but requires a blast with charcoal or other solid combustible. The brass was not melted, so the highest temperature obtained in the hottest corner of the tower was therefore less than 1,950°, and much less elsewhere. It was further claimed on the part of the defendants that the fracture of one pulley would not necessarily fracture the next one on the line, and that of the next and so on, and produce the train of breakages in the order claimed by the plaintiffs. The plaintiffs showed that one of the pieces of the line shaft alongside the first pulley that broke was fractured, and claimed that this was done by that pulley fouling at the time of the short circuit, bringing a jar on the pillow block, which caused a disruption of the next pulley and that in turn the next, but this was answered by the fact that no other pier was injured and that no great shock could be transmitted beyond the next journal. There were two journals before reaching the two on either side of the jack pulley, neither one of the four being disturbed, and a friction clutch intervened. The defendants claimed that the pieces of the first pulley, which it was in testimony flew up and struck the ceiling and the switch board, could not, in the limited height available, spread very greatly, and that therefore no piece of the first pulley could fly off at an angle of 40 to 45° for a distance of about 40 ft. and break the governor of the engine at the outset, and it was stated that, if it did, the engine would still be under control.

It is possible that failure of a pulley or fly wheel may commence nearer one edge than the other and thereby tend slightly to disperse the pieces, but the breakage entirely across the face would follow so nearly at the same instant that the component of force due to the velocity in the plane of the wheel would be much the greater, and only such of the flying particles as flew high in the air could disperse laterally any considerable distance. Any piece that was thrown straight up after the roof or other obstructions had been removed would, with an initial velocity of 19,235 ft. per second, rise to a height of nearly 1,000 ft., or say over 1,000 ft., allowing for the resistance of the air, and such piece in falling, if diverted to the slightest extent, might reach to a considerable distance laterally, though such a result would be prevented by obstructions in a building. One of the most interesting experiences during the bombardment of Forts Jackson and St. Philip, on the Mississippi River, by the Porter bomb fleet, as told by soldiers of the Southern army afterward, was the way in which the pieces of shell scattered. In most cases the shells, coming down nearly vertically, buried themselves in the mud, and merely threw up a large volume of it, causing a general scattering of the groups of soldiers for the moment and a laugh afterward. Sometimes men playing at cards would run like mice to the casemates and avoid the direct result of an explosion and then be back as quickly to their positions in the game, and on several occasions after they had all returned and were laughing over the last Yankee shot, and noting the discomfiture of some one who was covered with mud, they would be startled by a sudden whirl, and the "lazy piece," as it was called, would come back from the skies and perhaps injure one or more of them. The "lazy piece" meant one thrown vertically upward at the time of the explosion, and which, therefore, being unobstructed, rose to a great height and took considerable time to rise and return.

It was also claimed by defendants that, if the jack pulley broke before the main fly wheel, and pieces of the former were carried on the belt underneath the latter, the upward strain would not necessarily break the fly wheel, or at least not without breaking the frame of the engine or the pillow blocks, cap, or bolts, which was not the case. The plaintiffs showed that the frame of the engine had been racked, but this the defendants accounted for by the shaking of the engine on its bed when running away.

The defendants, the insurance companies, after an-

swering the theories of the plaintiffs, claimed that the whole accident was caused by the running away of the engine, due to the slackness of the governor belt or the slipping out of the lacing, whereby the governor acted rather slowly or entirely ceased to act. No safety attachment was provided for such an emergency, but the engineers have applied one since the accident. As to the cause of the fire, it only required a little moisture on the wood of the tower to which the lightning arresters were screwed to cause a slight leakage between the terminals of the dynamo when a very moderate increase of electromotive force would cause additional current to cross the shunt formed by this leakage, and char the wood so that it would become a good conductor and thus form a short circuit, which, though only throwing out say one-fourth the lights, would start the wood-work in a blaze and cause the slight damage by fire in the tower, which, apparently, cost only about one hundred dollars to repair.

It was in evidence that the governor belt was new, though this was denied by the engineer in charge. An engine controlled through a governor belt with the lacing coming out would accelerate speed quite rapidly, and the speaker claimed that if the current regulator of dynamos required 10 to 15 seconds after a short circuit to control the current, as claimed by plaintiffs' experts, it would also fail to promptly control the current due to a rapid increase of voltage from rapid acceleration of the speed of the engine and dynamo and cause a short circuit and the fire, and that at any rate it was doubtful if the regulator could control the current within unusual limits such as would obtain if the speed of dynamo were doubled, or much less if it raised from 850 to over 3,000 revolutions per minute, as would have been the case if the engine ran away. In answering this the T. & H. expert made another close distinction, as he claimed that, though the regulator was slow in checking an electrical phenomenon like a short circuit, still, being itself operated by electricity, it really changed at a faster rate than it was possible to cause a mechanical change, such as an acceleration of the engines. This by no means follows, as it will be shown that the engine would quadruple its speed and that of the dynamos in 70 seconds or less, according to the work being done. The T. & H. expert, however, acknowledged that it was doubtful if the regulator would control the current when the speed of dynamo increased to more than 1,700 revolutions per minute. The insurance companies also put in the evidence of an electrician that one of the station transformers was burned out, indicating increased speed of the alternator and exciter, but the other side denied this. The plaintiffs put in testimony that any increase of speed would have been noticed at the start, but evidently men occupied with a fire might not observe it. The roaring noise heard by the fireman could not have been that due to a short circuit which instantaneously caused the break on the theory of the plaintiffs, as the noise and the breakage were, according to such theory, coincident and over in an instant. A man who was called from the fire room, therefore, could not have heard the roar, so called, of a short circuit before the breakage occurred. He could, however, have heard the increased buzz due to the more rapid passage of the gaps between the commutator segments under the brushes. The defendants naturally suggested that the men did observe that the engine was running away, and that the watchman went to the throttle valve for that reason and commenced closing it, but by that time the speed was so great that the pulleys of largest diameter on line shaft were being disrupted by centrifugal force, and it is probable that the one driving the dynamos, being slightly distorted by regular strain, was the first one to go and that the others of same diameter on the line shaft followed in succession. The acceleration of speed once started could not be controlled by the governor belt, so the speed increased until the main fly wheel was disrupted by centrifugal force, breaking the jack pulley, throwing down the roof of the building and cutting a gap in the roof and sides.

The plaintiffs claimed that if the speed of the alternator and exciter increased, the lamps would have been brighter, but evidently the man would not have noticed this if occupied with the fire. They also claimed that since the rim speed of the armatures was greater than that of the pulleys they should have been disrupted first, which was answered by the statement that the materials of the armatures were of higher tensile strength. In fact, the globular shape of the armatures of the are light T. & H. machines is well adapted to prevent any injury to the winding by centrifugal force, and the wrought iron cores of the spools in the alternator were evidently able to resist much more speed than any cast iron construction. Tests were made by the plaintiffs to find if a governor like that on this engine would regulate with one ball in use. The sleeve lifted by a governor of this size was quite heavy, so it was found that the speed of engine under such circumstances would have been increased to about 118 revolutions per minute, but even this was well within the safe limit even of the pulleys with the most rapid rim speeds.

The speaker made calculations to determine the speed at which the engine and several pulleys would be disrupted by centrifugal force. The normal speed of the rim of the fly wheel at the diameter of the approximate radius of gyration was 4,715 feet or nine-tenths of a mile per minute. The rim speed of the jack pulley must therefore have been substantially the same or a trifle less on account of slip, and the rim speed of the 6 foot pulleys on the shaft operating the dynamos as well as the rim speed of the pulleys of the dynamos themselves have been about 50 per cent. greater than that of the fly wheel. From the formula above given it was calculated that for a tensile strength of 10,000 pounds per square inch the fly wheel should have been disrupted at 310½ revolutions per minute, or roughly, four times the normal speed. The 6 foot pulleys on the jack shaft should, however, have been disrupted when the engine was running at a speed of 307 revolutions per minute. In order to ascertain approximately the time it would require for an engine under these conditions to run to destruction in case the governor belt were entirely disabled, it was assumed that even with the increased draught on steam pipe, due to running away, a mean pressure of 48 pounds would be obtained, referred to the large cylinder. By "referred" we mean simply that the mean pressure in the small cylinder,

divided by the ratio of the area of the two cylinders, is added to the actual pressure in the large cylinder. This mean pressure was sufficient to give 900 horse power at normal speed, and of course the power increased with the speed. It was, however, considered that 13½ pounds mean pressure out of the 48 were required until the first pulley broke to operate the dynamos and shafting, this pressure being sufficient to produce 253 horse power at normal speed, which is probably a liberal allowance. The mean pressure of 48 pounds is also well within limits, at least for the initial increase of speed, so the time stated hereafter as required to destroy the wheels is probably somewhat greater than would be the case in practice. To ascertain such time it was considered that not only the fly wheel but every pulley connected therewith, as well as the armatures of the dynamos, really formed fly wheels which would require force either to accelerate or retard their velocity. To ascertain the effect on the result, the revolving weights of each were ascertained or estimated and multiplied by the ratio of the speed of same to that of the fly wheel. The sum of these quantities showed the additional weight which it would require in the fly wheel rim to produce the same result. It was found that the aggregate result was the same as if 10,190 pounds had been added to the fly wheel rim, making it weigh practically 48,000 pounds instead of 38,000.

On this basis it was calculated that it would require 45 seconds for the engine to increase its speed from 76 revolutions to 207 revolutions, when, on the basis of 10,000 tensile strength, the pulleys on the line shaft should have been disrupted, and as the disruption of such pulleys would have reduced the load on the engine, with the exception of friction, it would only have required 27 seconds, or in round numbers 1½ minutes from the beginning, to raise the speed to 310½ revolutions per minute and disrupt the fly wheel. There was testimony in the case to the effect that the engineer on watch confessed to his brother engineer that when the fire in the tower was discovered, he pulled the plugs cutting out the are lights and thus released the load on the dynamos. With this state of facts the load on the engine would have been released earlier and the time required to run to destruction have been diminished. If, however, the governor belt was not broken, but simply slack, so that it took care of changes of load slowly, the acceleration could have progressed at a much less rapid rate.

From what has been stated, it will be seen that the combined mechanical and electrical conditions involved in an accident to an electric light plant involve even greater refinements and complications in tracing cause and effect than has heretofore been the case with simple mechanical questions. It will also be observed that a very important question of principle arises in relation to damages occurring in connection with a fire, but not actually caused by the action of the fire itself. It has become necessary in many of the States, by law and judicial decisions, to exclude what are called "consequential damages," particularly in relation to public works, and this was founded on precedents long established in the older countries. For instance, under the common law a man in digging on his own land was not responsible for damages to a building on adjoining property. It is well understood that a man who fails to pay a debt is only liable for the amount of the debt and interest, although his delay may have caused failures which injured many other persons. So, also, in case of accident, or, in fact, of any injurious change of condition, there is always a direct result followed by others more or less indirect also in the nature of damage. The indirect results are so far-reaching, a damage to one causing more or less injury to another, that litigation would never cease unless some legal estoppel were put upon it, as has been done in relation to many kinds of transactions. Evidently, occurrences of a kind like that in the electric light station will have the effect of causing some such limitation in regard to insurance. If a fire which caused a direct damage of only \$100 by fire, and immediate injury to only a few hundred dollars of fixtures in the neighborhood, can, in addition, be charged with the cost of injuries caused by a runaway engine, there might conditions arise where still further consequential damages would go on almost without end. For instance, questions of personal injury might be involved from many people struck by flying fragments, or a large fragment might knock down a draw bridge in the vicinity and wreck a train of cars, or such a fragment might strike a vessel loaded with explosives and cause a gunpowder or dynamite explosion which would wreck the whole neighborhood, and if such explosives were required for use by a then friendly government, and that government failed to prevail in an impending war for a lack of such material, the one hundred dollar fire in the beginning might cause international complications and result in a general war. Somewhere in the progress from first cause to final effect the law of consequential damages should, and will, sooner or later, be made to apply, and special policies will be written when accidents to machinery are to be included. Without anticipating what will be done, it would seem natural to limit the damage at a point where the carelessness of the employees or of the insured, by defects in mechanism or material, caused the increased damage. In the case under discussion the judge was obliged to hold that under the law as then adjudicated, even if the pulley was defective which it was claimed broke first, so that it broke with less strain than such pulleys should, still the insurance companies would be liable. Evidently, if this were the case, any slight accident, such as short-circuiting the electric lights outside but near the station, or the dropping of a tool in some part of the machinery, might, without fire, have caused the other more important damages. It, therefore, appears equitable that at such a break in the chain as this, a limitation of damage arising from fire should be made, on the general principles that have made it necessary to provide limitations in other cases, and also on a principle like that of contributory negligence in case of personal injury, whereby it would be provided that whenever the insured were themselves also at fault, either through the action of their employees or by the use of defective machinery, which would be liable to cause such accident without fire, the damages from fire should be limited at that point. Who knows but what the courts may finally hold that this is a fair interpretation of the law as it stands?

MACHINE FOR MEASURING FABRICS.

This is an improved machine, made by the Fabric Measuring Machine Co., Bradford, for measuring fabrics in rolls or folds, without unrolling or unfolding the goods. Fig. 1 gives a small view of this machine.

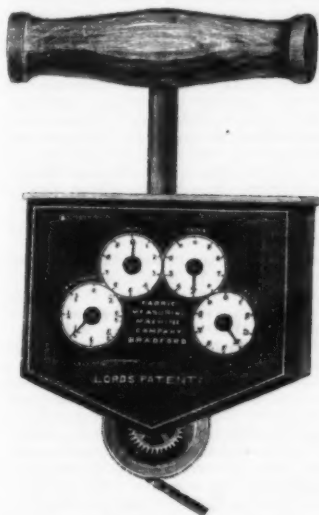


FIG. 1.—MACHINE FOR MEASURING FABRICS.

chine, which, it will be noticed, has a guide fixed at the bottom of the mechanism. This guide is inserted between the layers of the fabric in a perpendicular direction, and so maintained during the process of measuring. Thus it will be seen that the machine must be held at an angle, as it has been found that this is the easiest position for speedy measuring. For other methods of measuring, noticed below, it is necessary to remove the guide; this can be done in a few seconds, as it is furnished with a screw thread, so that it can be readily unscrewed from the machine. Fig. 2 gives an illustration of the machine mounted on an adjustable bracket, in order that it may be easily fixed to a measuring table. In this form it allows the measur-

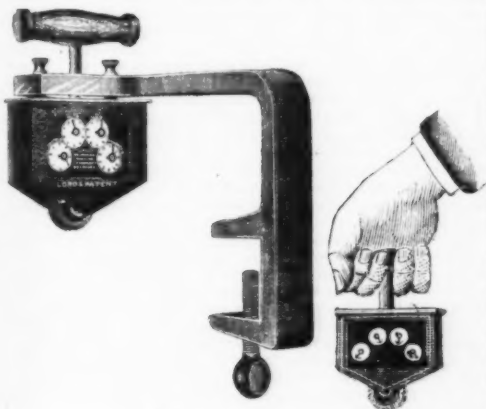


FIG. 2.

FIG. 4.

ing wheel to measure and indicate the length of any description of piece goods, from the finest silk to the heaviest woolen fabrics. The apparatus can be fixed to the bracket and clamped to a table in a few seconds, when it is ready for the measuring operation, which is carried out as shown in Fig. 3. One end of the fabric is brought under the measuring wheel, and the two screws at the top of the machine are turned a little, until the measuring wheel presses slightly upon the fabric; the latter can then be drawn forward over the table as quick as the operator thinks fit, the index dial indicating the exact measurement of the fabric so drawn forward under the wheel. So accurate is the mechanism that, if the above instructions are followed out, it

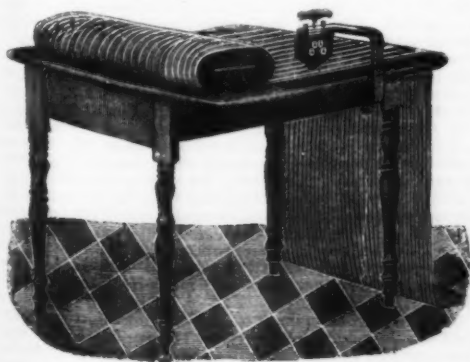


FIG. 3.

is totally impossible for the indicator to give any wrong measure, and so simple is the mode of operating that the work can be done efficiently without any previous instruction whatever. Fabrics of nearly all classes can be measured at the rate of 100 yards in three minutes, and, in many cases, at a much quicker rate. Beneath the two screws above mentioned is a spring, and, if the former are properly adjusted, the spring acts in the form of a brake, so that, no matter how rapidly

the machine may be running, the moment the end of the fabric leaves the machine, the dials cease to indicate immediately. Fig. 4 is an illustration of the same machine when removed from the bracket, which can be done in thirty seconds. It is then ready for use as a hand measure, and by simply holding it in the hand, as shown in illustration, and running it along lengths of fabrics lying upon a table or counter, the exact measurement of such lengths are accurately indicated upon the index dial. The machine thus may be used in a three-fold capacity, viz.: First, for measuring pieces in rolls or folds; secondly, for fixing by the bracket to the measuring table; and thirdly, for use as a hand measurer. It will prove a decided benefit to manufacturers, merchants, drapers, tailors, and, in fact, to all engaged in the textile trades. For stock-taking purposes it will be invaluable, saving time and money. It has already been highly spoken of by the various textile trade papers, and it is with the utmost confidence that we speak in its favor, as we have had every opportunity of judging of its merits.—*Textile Indus.*

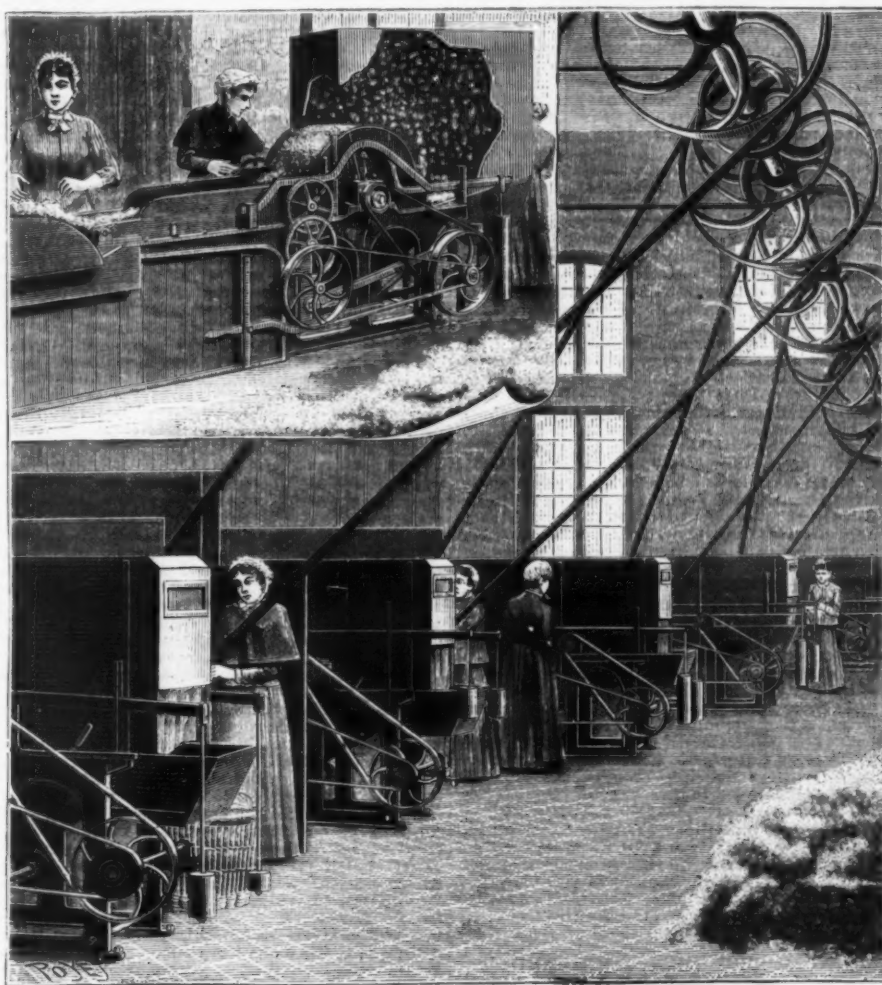
THE OLD RAG INDUSTRY.*

Shoddy Wool.—Up to 1840, woolen rags were used in France for but one purpose, and that was for fertilizing the soil. It is related that one evening during the winter of 1838, a peasant of Maine-et-Loire was amusing himself with unraveling the knit stockings that he wore, and the holes in which bore witness to a prolonged use. After he had got together a certain number of ravelings, the idea occurred to him to card

These various sorts of products have given rise to the manufacture of two very distinct qualities, the *mungo* and *shoddy*. These appellations, which are of English origin, lead us to say that we are indebted to England for the true processes of the industry that occupies us, and the present center of which is at Dewsbury, where, for a long time before the discovery of raveling, there existed machines which cut up blanketing. The product, which was sold to upholsterers and saddlers, served to replace woolen in mattresses and for covering furniture and horse appointments.

When Mr. Parr, the inventor of the first raveling machine, had produced his first ball of wool, he did not at first foresee the possibility of selling it for the manufacture of cloth therefrom. He was even advised to stop the running of his machine. He answered in the Yorkshire dialect: *A mun go, "it must go."* This expression has remained as a trade term, *mungo*, which designates everything made of fulled cloths. As for the term *shoddy*, that is applied to everything made from carded or knit wool, blanketing, carpeting, swan skin, etc.

Now that our readers are superficially initiated, we shall enter a raveling works, a part of which is represented in our engraving. But, in the first place, let us see what treatment the raw material undergoes. On their arrival, the rags are beaten mechanically in order to expel the last traces of dust that has been left after sorting. After being beaten, they are carefully classified according to their nature, and are then classified according to color and shades of color. Thus the blues give ten shades, the maroons four,



SHODDY RAG MACHINES.

them; and, as he had seen done, he oiled his product in order to better prepare it for the comb, and especially to ward off all suspicions as to its origin. Then, provided with the wool obtained, he visited a spinner and asked him if he could turn it to any account. An affirmative answer being received, a bargain was made, and our peasant immediately bought up all the old blue stockings that he could find, this color having been exacted of him by the spinner, who found therein a saving in dyeing of at least two francs per kilogramme. Starting from this moment, the trade in woolen rags and the "regenerated wool" industry entered its embryonic period; we say *embryonic*, for, in order to reach the state in which we now find this industry, how many vexations were to be met with and how many difficulties to be overcome! Along with material obstacles was encountered the ill will of the spinner, the fuller and the merchant, who refused to work or sell the new product. Nevertheless, such ill will disappeared in presence of the profit to be made, while, at the same time, the obstacles vanished under the efforts of progress. The new industry prepared the way for another one, whose development has been very rapid, i. e., that of the manufacture of clothing on a large scale, thanks to which, the poorer classes can now substitute woolen for cotton garments.

At the beginning of the industry of raveling rags, the rudimentary state of the machines permitted of working only certain categories of them, such as tricots. In measure as improvements were made, swan skins, old flannels, and merinos were raveled. Progress ever continuing, woolen cloths and even felts were treated.

the greens three, etc. This sorting terminated, each shade is taken up again and submitted to a close examination, during the course of which every trace of cotton must disappear. Cotton warp rags are treated in a special manner called carbonizing, of which we shall speak hereafter. After these various operations, the rags are oiled for the purpose of facilitating a portion of the ulterior mechanical transformations. The material employed for this is olive oil or oleic acid, the latter by preference, because the scouring is effected more easily and more rapidly than if a vegetable oil were used. The operation of oiling consists in spreading the rags out in thin layers and impregnating them with olein in a proportion that varies with their nature and weight. In this state the rags are ready for raveling, an operation that is effected in the machines that are shown in the engraving, and the details of which are shown more completely in the upper corner of the figure.

The principal part of these machines is a drum of a diameter that varies between 50 centimeters and one meter, and is provided on its external surface with from 8,000 to 12,000 steel points. The rags are distributed by female operatives over an endless belt of canvas, and engage between two fluted cylinders, called feeders, which turn at the rate of from 5 to 12 revolutions per minute, according to the stiffness of the material treated. The steel points pass at from one to two millimeters. What occurs may be easily guessed. As soon as the rag presents itself, it is cut up in some measure by the steel points of the revolving drum. The raveled wool remains under the form of down between the points, and is carried to a box, placed under the machine, through the energetic action of the current of

* Continued from SUPPLEMENT, No. 818, p. 13007.

air produced by the rapid rotary motion of the system. If the pieces of rags are torn away without being raveled, they are thrown at a tangent with the drum, by virtue of their weight and of centrifugal force, against the sides of the cover, and fall into a sort of trough placed at the extremity of the machine, whence they are taken and placed again upon the endless belt. All the machines are provided with a cover of wood, in order to prevent the products of one from mixing with those of another whose color is not the same. Counterpoises placed at the extremity of lever arms act upon the feeders and increase or diminish the pressure of the cylinders according as one has to do with mungo or shoddy.

The wool converted into down is afterward submitted to the action of a carding roller, which converts it into a light, continuous fleece, about a meter in width. In this state, the shoddy wool is ready for spinning.

The art of the raveler does not consist alone in the superintendence of the forementioned operations, but it is necessary for him to solve certain problems that require a profound knowledge of the combination of colors. When he ravelers blue, maroon or white rags, it is unnecessary to say that he obtains blue, maroon or white shoddy wool; but the spinner often has need of intermediate shades, and sends a specimen to the raveler, who is obliged to furnish a like product. We have been enabled to see a blue shade obtained by mixing, during the raveling, rags derived from soldiers' cloaks with rags from the garments of postmen. The result in shoddy wool was identical with the specimen. Aside from the question of color comes the no less difficult one of price. In order to satisfy this, our manufacturer has recourse to mixtures of different qualities, old and new rags for example; and, indeed, it is necessary to belong to the fraternity in order to discover the stratagem, which is found out by good judges, thanks to a phenomenon of dichroism not easy to perceive. The spinner, on his side, makes mixtures of fine wool and shoddy that are dictated to him by the selling price. It follows that certain fabrics are manufactured entirely from shoddy wool.

What we have just said amply suffices to give an idea of the enormous development that the shoddy wool industry has assumed, and the influence of which has made itself felt in the price of rags, for which 3 or 4 francs per 100 kilogrammes were formerly paid, and which are worth to-day 30 francs per 100 kilogrammes. So this trade, as well as the industries connected therewith, represents a large business movement. It may be admitted that every inhabitant of France annually throws aside at least 8 kilogrammes of woollen fabrics, representing, for thirty-six million individuals, a figure of two hundred and eighty-eight million kilogrammes, the value of which may be estimated at one hundred and fifty million francs.

On another hand, admitting that a small sized sheep yields 1.5 kilogrammes or 2.5 kilogrammes of wool, and that a large sized one yields from 5 to 8, that makes an average of 4 kilogrammes per head, from which it is necessary to deduct a loss of 4 per cent. After washing, scouring, etc., we have 2.4 kilogrammes of utilizable wool. A very simple calculation will show that it would require more than one hundred million sheep to replace artificial wool—a quantity which is far from existing in France.

It remains for us to say a few words regarding the treatment of cotton warp rags, in which the wool alone is of wool, which it is necessary to separate. This treatment, called carbonization, consists in submitting the rags in question to the action of hydrochloric acid gas in chambers or apparatus constructed for the purpose. The gas attacks the vegetable portion of the fabric, and which a simple beating and brushing suffices to eliminate, leaving intact the threads of wool, which are thus ready to undergo raveling. Different improved rotary apparatus have been devised, but the principle remains the same; it is, moreover, that known in the weaving industry as burling.

We must not terminate this article without thanking Mr. G. Deffaux, by whom we were most warmly received, and who, in putting his works at our disposal, explained to us the different details of the manufacture of shoddy wool, and who in this task was aided by Mr. E. Michel.—P. Gahery, in *La Nature*.

THE NEW ASTRONOMY: ITS METHODS AND RESULTS.

By Sir ROBERT S. BALL.

ASTRONOMERS are at present endeavoring to become fully acquainted with the resources of a new tool which has recently been placed in their hands. Perhaps it would be rather more correct to say that the tool is not exactly novel in principle, but it is rather the development of its capabilities and its application in new directions that forms the departure now creating so much interest. We have already learned much by its aid, while the expectation of further discoveries is so well founded that it is doubtful whether at any time since the invention of the telescope the prospects of the practical astronomer have seemed so bright as they are at this moment.

In the earlier periods of astronomical research it was the movements of the heavenly bodies which specially claimed attention, and it was with reference to these movements that the great classical achievements of the science have been made. But within the last two or three decades the most striking discoveries in observational astronomy have been chiefly through by no means exclusively concerned with the physical constitution of the heavenly bodies. It is the application of the spectroscopic by the labors of Dr. Huggins and others that has disclosed to some extent the material elements present in the stars, as well as in comets and the distant nebulae. Now, however, it seems as if the spectroscopic were for the future to be utilized not merely for that chemical examination of objects which is in the scope of no other method, but also as a means of advancing in a particular way our knowledge of the movements of the heavenly bodies. The results already obtained are of a striking and interesting description, and it is to their exposition and development that this article is devoted.

In the first place, it will be observed that the application of the spectroscopic which we are now consider-

ing is not merely to be regarded as an improvement superseding the older methods of determining the movements of stars. It is, indeed, not a little remarkable that the type of information yielded by the spectroscopic is wholly distinct from that which the earlier processes were adapted to give. The new method of observing movements, and that which, for convenience, we may speak of as the telescopic method, are not, in fact, competitive contrivances for obtaining the same results. They are rather to be regarded as complementary, each being just adapted to render the kind of information that the other is incompetent to afford.

It is well known that the ordinary expression, *fixed star*, is a misnomer, for almost every star which has been observed long enough is seen to be in motion. Indeed, it is not at all likely, nay, it is infinitely improbable, that such an object as a really fixed star actually exists. When the place of a star has been accurately determined by measurements made with the meridian circle, and when, after the lapse of a number of years, the place of the same star is again determined by observation, it not unfrequently happens that the two places disagree. The explanation is, of course, that the star has moved in the interval. Thus the constellations are becoming gradually transformed by the movements of the several stars which form them. It is true that the movements are so slow that even in thousands of years the changes do not amount to much when regarded as a disturbance of the configuration. Thus, to take an example, we know the movements of the stars forming the Great Bear sufficiently well to be able to sketch the position of the stars as they were ten thousand years ago, or as they will be in ten thousand years to come, and though, no doubt, some distortion is shown in each of these pictures from the present lineaments of the Great Bear, yet the identity of the group is in each case well preserved.

It is, however, obvious that if a star should happen to be darting directly toward the observer or directly from him, the telescopic method of determining its movement becomes wholly inapplicable. No change in its position could be noticed. It is, no doubt, conceivable that if the distance of a star from the earth were determined, and if the investigation were repeated after a sufficient lapse of time, then the differences between the two distances would give an indication of the star's movement along the line of sight during the interval. But we may say at once that such a method of research is wholly impracticable. Our knowledge of the star distances is far too imperfect for the successful application of this method. Nor is there the slightest prospect of any improvements in practical astronomy which could enable us to detect movements of stars in the line of sight in the way suggested. Certainly it offers no hope of a method which could compare for a moment in simplicity or precision with the beautiful spectroscopic process. Of course if a star were moving in the line of sight, there must be a certain change in its apparent luster corresponding to the changes in its distance, and it might be supposed that by careful measurements of the brightness of a star conducted from time to time, conclusions could be drawn as to the speed with which it was moving. But the application of such a process is beyond the sphere of available methods. It would take at least a thousand years before even the most rapidly moving star would experience a change that would sensibly affect its luster; and even if we had the means of measuring with precision the light emitted, our results would still be affected by the possible fluctuations in the star's intrinsic brightness. It is thus manifest that the resources of the older astronomy were quite incapable of meeting the demands of astronomers when it became necessary to learn the movements of the stars to us or from us as well as the movements perpendicular to the line of vision, which had always been the subject of much investigation. It is just here that the spectroscopic comes in to fill the vacant place in the armory of the astronomer. It tells exactly what the older methods were unable to tell, and it does so with a certainty and a facility that suggest vast possibilities for the spectroscopic process in the future. The principle of the method is a beautiful illustration of the extent to which the different branches of physical science are interwoven. But the principle has been a familiar one to astronomers for many years. It is the facility and success attending its recent application that has now aroused so much interest. Once it became certain that the undulatory theory of light expressed a great truth of nature, a certain deduction from that truth became almost obvious. It was, however, by no means certain that the practical application of this deduction to astronomical research would be feasible. That it has proved to be so in any degree is somewhat of a surprise, while it now appears susceptible of developments to an extent that could hardly have been dreamed of.

The logic of the new method is simple enough. Our eyes are so constituted that, when a certain number of ethereal vibrations per second are received by the nerves of the retina, the brain interprets the effect to mean that a ray of, let us say, red light has entered the eye. A certain larger number of vibrations per second is similarly understood by the brain to imply the presence of blue light on the retina. Each particular hue of the spectrum—the red, orange, yellow, green, blue, indigo, violet—is associated with a corresponding number of vibrations per second. It will thus be seen that the interpretation we put on any ray of light depends solely, as far as its hue is concerned, on the number of vibrations per second produced on the retina. Increase that number of vibrations in any way, then the hue shifts toward one nearer the blue end of the spectrum; decrease the number of vibrations per second, and the hue shifts along the spectrum in the opposite direction.

From these considerations it is apparent that the hue of a light as interpreted by the eye will undergo modification if the source from which the light radiates is moving toward us or moving from us. In order to expound the matter simply, I shall suppose a case of a rather simpler type than any which we actually find in nature. Let us suppose the existence of a star emitting light of a pure green color corresponding to a tint near the middle of the spectrum. This star pours forth each second a certain number of vibrations appropriate to its particular color, and if the star be at rest relatively to the eye, then, we assume, the vibrations will be received on the retina at the same intervals as those with

which the star emits them. Consequently, we shall perceive the star to be green. But now suppose that the star is hurrying toward us, it follows that the number of vibrations received in a second by the eye will undergo an increase. For the relative movement is the same as if the earth were rushing toward the star. In this case we advance, as it were, to meet the waves, and consequently receive them at less intervals than if we were to wait for their arrival. Many illustrations can be given of the simple principle here involved. Suppose that a number of soldiers are walking past in single file, and that while the observer stands still twenty soldiers a minute pass him. But now let him walk in the opposite direction to the soldiers, then, if his speed be as great as theirs, he will pass forty soldiers a minute instead of twenty. If his speed were half that of the soldiers, then he would pass thirty a minute, so that, in fact, the speed with which the observer is moving could be determined if he counts the number of soldiers that he passes per minute, and makes a simple calculation.

On the other hand, suppose that the observer walks in the same direction as the soldiers; if he maintains the same pace that they do, then it is plain that no soldiers at all will pass him while he walks. If he moves at half their rate, then ten soldiers will pass him each minute. From these considerations it will be sufficiently apparent that if the earth and the star are approaching each other, more waves of light per second will be received on the retina than if their positions are relatively stationary. But the interpretation which the brain will put on this accession to the number of waves per second is that the hue of the light is altered to some shade nearer the blue end of the spectrum; in fact, if we could conceive the velocity with which the bodies approached to be sufficiently augmented, the color of the star would seem to change from green to blue, from blue to indigo, from indigo to violet; while, if the pace was still further increased, it is absolutely certain that the waves would be poured upon the retina with such rapidity that no nerves there present would be competent to deal with them, and the star would actually disappear from vision. It may, however, be remarked that the velocity required to produce such a condition as we have supposed is altogether in excess of any known velocities in the celestial movements. The actual changes in hue that the movements we meet with are competent to effect are much smaller than in the case given as an illustration.

On the other hand, we may consider the original green star and the earth to be moving apart from each other. The effect of this is that the number of waves poured into the eye is lessened, and accordingly the brain interprets this to imply that the hue of the star has shifted from the green to the red end of the spectrum. If the speed with which the bodies increase their distance be sufficiently large, the green may transform into a yellow, the yellow into an orange, the orange into a red; while a still greater velocity is, at all events, conceivable which would cause the undulations to be received with such slowness that the nature of the light could no longer be interpreted by any nerves which the eye contains, and from the mere fact of its rapid motion away from us the star would become invisible. Here, again, we must add the remark that the actual velocities animating the heavenly bodies are not large enough to allow of the extreme results now indicated.

However, in the actual circumstances of the celestial bodies it seems impossible that any change of hue recognizable by the eye could be attributed to movement in the line of sight. Nor does this merely depend on the circumstance that the velocities are too small to produce such an effect. It must be remembered that the case of a star which dispenses light of perfect simplicity of composition is one that can hardly exist among the heavenly bodies, though it may be admitted that there is a certain approach to it in one or two remarkable cases.

It is, however, much more usual for the light from a star to be of a highly composite type, including rays not only from all parts of the visual spectrum, but also of rays belonging to the ultra-violet region, as well as others beyond the extreme red end. The effect of the retreat of a star, so far as its color is concerned, is that, though the green is shifted a little toward the red, a bluish hue moves up to supply the place of the green, and as a similar effect takes place along the entire length of the spectrum, the total appearance is unaltered.

It is a fortunate circumstance that the lines in the spectrum afford a precise means of measuring the extent of the shift due to motion. If the movement of the star be toward us, then the whole system of lines is shifted toward the blue end, whereas it moves toward the red end when the star is hastening from us. The amount of the shift is a measure of the speed of the movement. This is the consideration which brings the process within the compass of practical astronomy. We need not here discuss the appliances, optical, mechanical, and photographic, by which an unexpected degree of precision has been given to the measurements. It seems that in the skillful hands of Vogel and Keeler it is possible in favorable cases to obtain determinations of the velocities of objects in the line of sight with a degree of precision which leaves no greater margin for doubt than about five per cent. of the total amount. It is truly astounding that such a degree of accuracy should be attainable under conditions of such difficulty. It must also be remembered that the distance of the object is here immaterial, unless in so far as the reduction in the brilliancy of the star, owing to its distance, involves a difficulty in making the observations.

As the first illustration of the extraordinary results that are now being obtained by the application of the new process, I take the case of the celebrated variable star Algol. This star is a well-known object to all star gazers; it lies in the constellation of Perseus, and its vagaries attracted notice in early times. In ages when the stars were worshiped as divinities it was not unreasonable to suppose that a star whose light varied in any extraordinary manner should naturally be viewed with some degree of suspicion as contrasted with stars that dispense their beams with uniformity. It was doubtless a feeling of this kind which rendered Algol a star of questionable import to the ancient students of the heavens. It was accordingly known as the Demon Star, for this is the equivalent of the name by which

we now know it. As to the peculiarities of Algol which have given it notoriety, these are very simply described. For two days and ten hours the star remains of uniform luster, being ranked about the second magnitude; then a decline of brightness sets in, and the star in a few hours parts with three-fifths of its brightness. At the lowest point it remains for about twenty minutes, and then the brilliancy commences to increase, so that in a few hours more Algol has resumed its original character. The entire period required for the decline and the rise is about ten hours, and the whole cycle of the changes has been determined with much accuracy, and is at present 2 days, 20 hours, 48 minutes, 52 seconds. The length of the period seems to undergo some trifling fluctuations of a few seconds, but on the whole the permanence of the system is a striking part of the phenomenon. Considering that these changes can be observed without any telescope, it is not surprising that they have been known for centuries. Indeed, it fortunately happens that there is a smaller star near Algol which serves as a convenient standard of comparison. Under ordinary circumstances Algol is much brighter than its neighbor, but when it sinks to its lowest point it then happens that the two stars have almost equal luster. It is only within the last year or two that the mystery of the variability of Algol has been at last revealed and the phenomenon of the Demon Star has received its true interpretation.

It had been suggested long ago that the loss of light might be due to an eclipse of the brilliant star by some dark companion; indeed, this theory seemed to hold the field, inasmuch as its only rival was one which supposed Algol to be a revolving body darker on one side than the other. This, however, was easily shown to be incompatible with the observed facts as to the manner in which the light waxed and waned in a single cycle of change. It was, however, impossible to subject the eclipse theory to any decisive test until astronomers were provided with the means of measuring the velocity of approach or retreat along the line of sight. The existence of the dark companion was therefore almost destitute of support from observations until Vogel made his wonderful discovery.

Applying the improved spectrographic process to Algol, he determined on one night that Algol was retreating at a speed of twenty-six miles a second. This in itself is a striking fact, but of course the velocity is not an exceptionally large one for celestial movements. We know of one star at least which moves half a dozen times as fast. When, however, Vogel came to repeat his observations he found that Algol was again moving with the same velocity, but this time the movement was toward the earth instead of from it. Here was indeed a singular circumstance, demanding the careful examination which it speedily received. It appeared that the movements of Algol to and fro were strictly periodic, that is to say, for one day and ten hours the star is moving toward us, and then for a like time it moves from us, the maximum speed in each advance or retreat being that we have mentioned, namely, twenty-six miles a second. The interest awakened by this discovery culminates when it appears that this movement to and fro is directly associated in a remarkable manner with the variation of Algol's luster. It is invariably found that every time the movement of retreat is completed the star loses its brilliancy, and regains it again at the commencement of the return movement. It is thus plain that the changes in brilliancy of the star bear an important relation to the periodic movement. Here was an important step taken. For the next advance in this remarkable investigation we have to depend, not on our instruments, but on the laws of mechanics. We have spoken of Algol as moving to and fro, but it is necessary to observe that it is impossible for a star to run along a straight line for a certain distance, stop, turn back, again retrace its movement, stop, and again return. Such movement is simply forbidden by the laws of motion. We can, however, easily ascertain that there is a type of motion possible for Algol which shall be compatible with the results of the spectroscopic research and also be permitted by the laws of motion. There is no objection to the supposition that Algol is moving in a path which is nearly, if not exactly, a circle. In this it would only be moving as does the moon, or the earth, or any of the other planets. It will be only necessary to suppose that the plane of the orbit of Algol is directed so that it passes near the earth. During the description of one semicircle Algol will be coming toward us, while during the other semicircle it will be going from us, and thus the observed facts of the movement are conciliated with the laws of motion. Of course, this involves a certain periodic shift in the position of Algol in the heavens. It must, for instance, when moving most rapidly from us, be at a distance equal to the diameter of the circle from the position which it has when moving most rapidly toward us. This is true, but the extent of the shift of place is far too small to be visible by our instruments; in fact, it can be shown that the size of the circle in which Algol revolves could hardly be larger than is that which the rim of a three-penny bit would appear to have if viewed from a situation five hundred miles away. It is one of the extraordinary characteristics of the spectroscopic method that it renders such an orbital movement perceptible.

The fact that Algol revolves in an orbit having been thus demonstrated, we can again call in the assistance of the laws of dynamics to carry us a step further. Such a movement is possible on one condition, and only one, and that is that there is an attracting body in the neighborhood around which Algol revolves. Of course, the student of mechanics knows that in such a case each of the bodies revolves around the other. The essential point to be noticed is that the spectroscopic evidence admits of no other interpretation save that there must be another mighty body in the immediate vicinity of Algol. We had already seen reason to believe in the possibility of the presence of such a companion for the Demon Star, simply from the fact of its variability. There cannot be any longer a doubt that the mystery has been solved. Algol must be attended by a companion star, which, if not absolutely as devoid of intrinsic light as the earth or the moon, is nevertheless dark relatively to Algol. Once in each period of revolution this obscure body intrudes between the earth and Algol, cutting off a portion of the direct light from the star, and thus producing the well

known effect. Here we have such a remarkable concurrence between the facts of observation and the laws of dynamics that it is impossible to doubt the explanation they provide of the variability of this famous star.

There is, however, a further point in which the facts can be made to yield information of even a more striking character, inasmuch as it is unique of its kind. It is, of course, well known that stars in general show no appreciable disks even in our best telescopes; in fact, the better the instrument, the smaller does the stellar point appear. This is, of course, due to the distance at which the stars are situated. It would be easy to show that if the sun were to be viewed by an observer placed on the nearest of the stars, the apparent magnitude of its disk would be no greater than an eagle would seem if soaring overhead at an altitude three times as great as the distance of New Zealand beneath our feet. Of course, no instrument whatever would render the dimensions of such an object perceptible, though such is the delicacy of the sense of perception of light that the eye may be able to detect the radiation from a self-luminous object which is itself too small to form an image of recognizable dimensions on the retina. The stars, of course, are suns often comparable with, and often far exceeding, our own sun in luster and dimensions, but their distance is far too large to enable us to measure their diameters by the ordinary processes of the observatory. Even if the stars were brought toward the earth so that their distances were reduced to a tenth of what they are at this moment, it does not seem at all likely that any one of them would be even then seen clearly enough to enable us to perceive its diameter. This statement becomes the more significant when it is borne in mind that there are several cases in which, though we are not able to measure the dimensions of stars, yet we are able to weigh them. If the period of revolution of a binary star has been determined, and if the distance of the pair from the sun is also known, we then have sufficient data to enable us to compare the mass of the binary system with that of the sun. It will therefore be understood that the first observations which declare the actual dimensions of a star merit the utmost attention. They constitute a distinct and important departure in our knowledge of the universe. It is surely a noteworthy epoch in the history of astronomy when, for the first time, we are able to apply the celestial calipers to gauge the diameter of a star. So far as surveying and measuring goes, this is the most significant piece of work in sidereal astronomy since the epoch, half a century ago, when the determination of a stellar distance first emerged from the mistiness of mere guess work and took a respectable position among the solved problems of astronomy. Nor is our gratification at the result of Vogel's striking work lessened by the fact of its unexpectedness. Who would have predicted some few years ago that the spectroscopic was to be the instrument to which we should be indebted for the means of putting a measuring tape round the girth of a star? The process and the results are alike full of interest and are of happy augury for the future.

To explain exactly how it is possible to deduce the diameter of Algol from the known facts of its movement would lead into some technicalities that need not be here mentioned. But the principle of the method is so plain that it would be unfruitful to leave it without some attempt at exposition. We are first to notice that Algol, at the moment of its greatest eclipse, has lost about three-fifths of its light; it therefore follows that the dark satellite must have covered three-fifths of the bright surface. It is also to be noticed that the period of maximum obscuration is about twenty minutes, and that we know the velocity of the bright star. These facts, added to our knowledge that ten hours is required for the brilliancy to sink from and regain its original luster, enable the sizes of the two globes to be found.

There is only one element of uncertainty in the matter. We have assumed that the densities of the two bodies are the same. Of course, this may not be the case, and if it should prove to be unfounded, then some modification will have to be made in the numerical elements now provisionally assigned. There can, however, be little doubt that, so far as the substantial features of the Algol system are concerned, the elements given by Vogel may be accepted. Let us endeavor to form a conception of what Algol and its companion are like. It is worth making the attempt, because, as we have already said, Algol is the first star among "yonder hundred million spheres" of which the dimensions are approximately known. First we are to think of Algol itself. It is indeed a vast object, a glowing globe, a veritable sun, much larger than our own. The diameter of the sun would have to be increased by almost 200,000 miles to make it as great as that of Algol. But we may exhibit the relative proportions of the two bodies in a somewhat different manner. Imagine two globes, each as large as our sun; let those two be rolled into one, and we have a globe of the splendid proportions of Algol. But now for a singular circumstance which indicates the variety of types of sun which the heavens offer to our study. Although Algol is twice as big as the sun, it is not twice as heavy. It is indeed an extraordinary circumstance that, notwithstanding the vast bulk of Algol, its weight is only about half that of the sun. The sun itself has a density about a fourth that of the earth, or but little more than the density of water, yet Algol has a density which is much less than that of water; in fact, this globe is apparently not much heavier than if it were made of cork. We are, of course, speaking of the average density of the star. No doubt its central portions must be dense enough, but it is impossible to resist the conclusions that the greater part of Algol must be composed of matter in a gaseous state. Of course, such a state of things is already known to exist in many celestial bodies. The figures that have been arrived at must be regarded as subject to a possible correction, but it is difficult to repress all feelings of enthusiasm at a moment when, for the first time, so startling an extension has been given to our knowledge of the universe. And now, as to the dark companion of Algol. Here is an object which we never have seen, and apparently never can expect to see, but yet we have been able not only to weigh it and to measure it, but also to determine its movements. It appears that the companion of Algol is about the same size as our sun, but has a mass only

one-fourth as great. This indicates the existence of a globe of matter which must be largely in the gaseous state, but which, nevertheless, seems to be devoid of intrinsic luminosity. We may compare this body with the planet Saturn; of course, the latter is not nearly so large as the companion to Algol, but the two globes seem to agree fairly well as to density. As to the character of the movements of the dark companion of Algol, we can learn little, except what the laws of dynamics may teach; but the information thus acquired is founded on such well understood principles that it leaves us in no uncertainty. It would be a natural assumption that the law of gravitation is obeyed and must be obeyed in the stellar systems. It would, indeed, be surprising if that law which regulates the movements of the bodies in the solar system should not be found to prevail in the sidereal systems also. Everything would justify us in the anticipation that this is so. Have we not learned to a large extent the actual nature of the elementary bodies which enter into the composition of stars? We find that the ingredients of these other suns are in the main identical with those which exist in our own sun and in the earth itself. If iron attracts iron by the law of gravitation in the solar system, why should not iron attract iron in the sidereal systems as well? But we are not dependent solely on this presumption for our knowledge of the important fact that the law of gravitation is not confined to the solar system. The movements of binary stars have been studied, and it has been invariably found that the phenomena observed are compatible with the supposition that the law of gravitation prevails throughout the universe. It would not, however, be correct to assert, as has been sometimes done, that the facts of the binary systems actually prove that gravitation is the all-compelling force there as here. The circumstances do not warrant us in expressing the matter quite so forcibly. The binary stars are so remote that the observations which we are enabled to make are wanting in the almost mathematical precision which we can give to such work when applied to the bodies of our own system. It is quite possible for mathematical ingenuity to devise a wholly arbitrary and imaginary system of force, which might explain the facts of binary stars, as far as we are able to observe them, on quite another hypothesis than the simple law that the attraction between two particles varies with the inverse square of the distance. No one, however, will be likely to doubt that it is the law of gravitation, pure and simple, which prevails in the celestial spaces, and consequently we are able to make use of it to explain the circumstances attending the movement of Algol's dark companion.

This body is the smaller of the two, and the speed with which it moves is double as great as that of Algol, so that it travels over as many miles in a second as an express train can get over in an hour. It revolves with apparent uniformity in an orbit which must be approximately circular, and it completes its journey in the brief period given above, which indicates the time of variability. So far the movements of Algol and its companion are not very dissimilar to movements in the solar system with which we are already familiar; but there is one point in which the Algol system presents features wholly without parallel in the planetary movements. It is that the two bodies are so very close together. I do not, of course, mean that they seem close by ordinary standards—for is not their distance always some three million miles? This is, however, an unusually short distance when compared with the dimensions of the two globes themselves. The dimensions of the system may be appreciated by the simple illustration of taking a shilling and a sixpence and placing them so that the distance from rim to rim is two inches. The smaller coin will represent the dark satellite and the larger one Algol, fairly correct as to position and dimensions. Viewed in this way it is evident that the dimensions of the globes bear a monstrous proportion to their distance apart when compared with the more familiar planets and satellites of our system. The tides in such a case must be of a magnitude and importance of which we have no conception from our experiences of such agencies here.

We have dwelt thus long on the subject of Algol because it was fitting to give due emphasis to the remarkable extension of our knowledge of the universe which took place when, for the first time, we became able to measure the size of a star.

It is well known that the most difficult test objects on which a telescope can be directed are some of those double stars of which the components have a suitable distance. If the two stars be so close together that they subtend at our system an angle not more than a few tenths of a second, then the telescopic separation of the two components is a feat to tax the powers of the most perfect instrument, and the eye of the most accomplished observer. It may, however, happen that there are double stars of which the components are much closer than this. In such a case there is not the slightest possibility of our being able to effect a visual decomposition of the pair into its components. The spectroscopic process has, however, placed at our disposal a striking method for detecting the existence of double stars so extraordinarily difficult that even if the components were hundreds of times farther apart than they actually are they would still fall short of the necessary distance at which they must be situated before they can be separated telescopically. Indeed, we have here obtained an accession to our power so remarkable that we have not yet been able even to feel the limits within which its application must be confined. As an illustration of this process I shall take a star which is probably as famous as Algol itself. It is Mizar, the middle star of the three which form the tail of the Great Bear. Mizar has in its vicinity the small star Alcor, which is now so easily seen as to make it hard for us to realize the significance of the proverb, "He can see Alcor." It is, however, possible that the luster of Alcor may have waxed greater since ancient times. The relationship between Mizar and Alcor is closer than might be inferred from the mere fact of their contiguity on the sky. Their proximity is not an accident of situation, as is the case in some other instances when two stars happen to lie in nearly the same line of vision. The association of Alcor and Mizar is rendered highly probable from the fact that they move together in parallel directions and the same velocity. But this is the least of the circumstances that give Mizar its interest. The star itself is a double

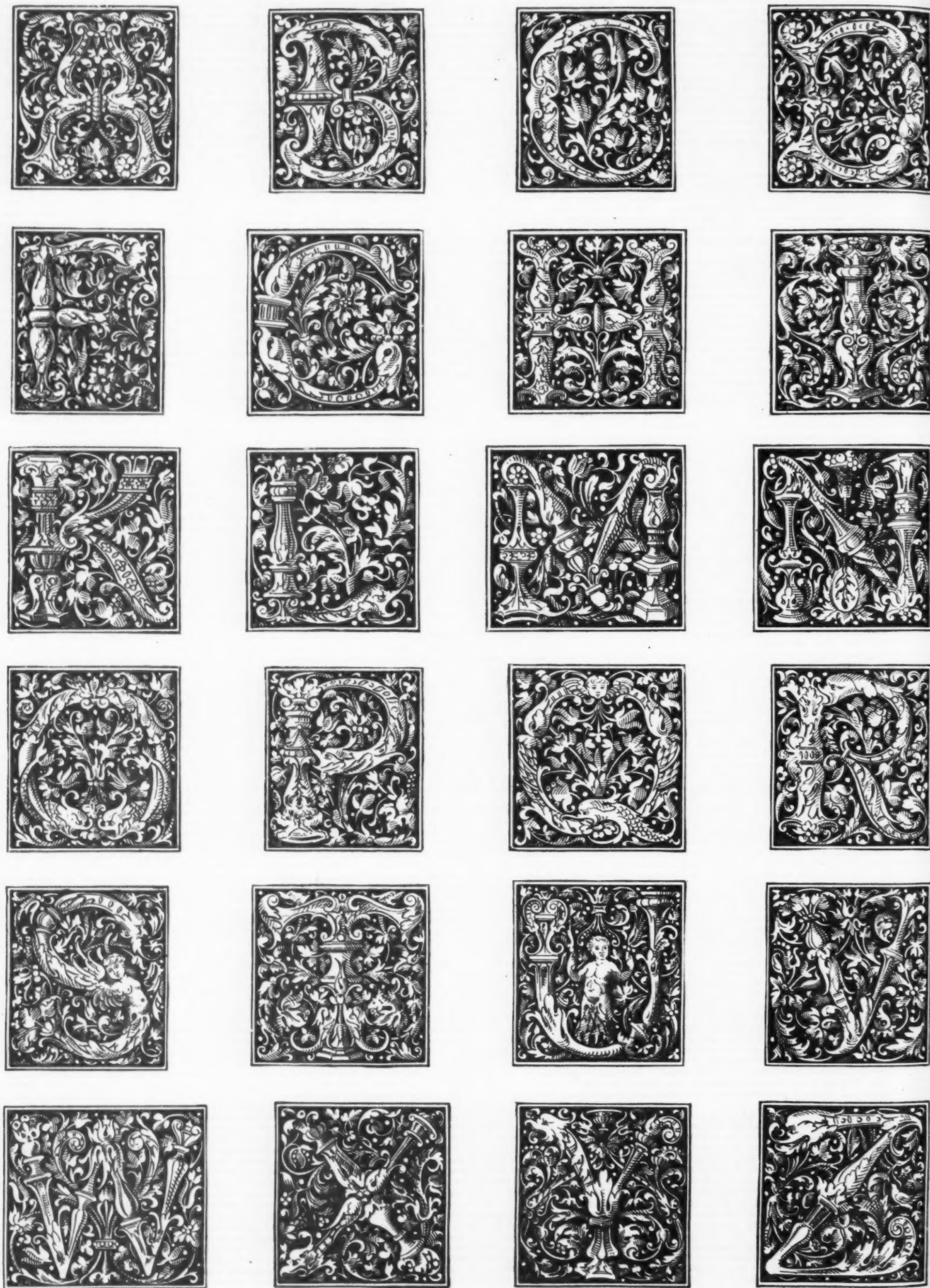


Photo-Lithographed & Printed by James Alderman, 6, Queen's Square, W.C.

DECORATIVE ALPHABET IN THE RENAISSANCE-STYLE
DESIGNED BY JAMES WEST.

of the easiest type, and is at the same time of striking interest and beauty. Every possessor of a telescope, large or small, knows Mizar to be one of the most suitable objects wherewith to delight the friends that visit his observatory, by a glimpse at a double star which is both easy to discern and remarkable in character. This is the second noteworthy point about Mizar; but now for the third and last, which is by far the most interesting of all, and has only lately been ascertained by a discovery which will take its place in the history of astronomy as the inauguration of a new process in the study of things sidereal.

Professor Pickering has, as is well known, been extremely successful in obtaining photographs of the spectra of the stars. Sufficient means having been placed at his disposal by Mrs. Draper, he has applied himself with remarkable results to the compilation of the Henry Draper memorial. The photographs of the spectra of the stars that he has obtained exhibit a fullness of detail that some years ago could hardly have been expected even in photographs of the solar spectrum itself. Among the stars subjected to his camera was Mizar, and the photographs of the spectrum of its principal component exhibited, as other stellar spectra did, a profusion of dark lines. These photographs being repeated at different dates, it was natural to compare them together, and it was noticed that the lines sometimes appeared double and sometimes single. So striking a circumstance, of course, demanded closer investigation, and presently it appeared that this opening and closing of the lines was a periodical phenomenon. The interval between one maximum opening of the lines and the next was fifty-two days. If the star were a single object, then this phenomenon would be inexplicable. It was plain that the object could not be a single star; it must consist of a pair extremely close together, and in rapid revolution. The doubling of the lines will then be readily intelligible. When one of the components is moving toward us while the other is moving from us, all the lines belonging to one system are shifted one way, and all those belonging to the other system are shifted the other way, the effect on the spectrum being that the lines appear doubled. When the stars are moving perpendicularly to the line of sight, then their relative velocities toward the earth are equal, and the lines close up again. We thus at once learn the period of the revolution of the two components. The lines must open out twice in each circuit, and consequently we have as the first installment of the numerical facts of the system that the period of its revolution is a hundred and four days. It is, however, a peculiarity of the spectroscopic process that it provides us with a wealth of information on the subject. The amount by which the lines open when they separate admits of accurate measurement, and as this depends on the velocities, it follows that we obtain a determination of these velocities. It thus appears that the speed with which each of the component stars moves is about fifty miles a second. As, therefore, we know the pace at which the stars are moving, and the time they need for the journey, we know how large their path is, and thus we infer that the distance of the components is, speaking roundly, about one hundred and fifty millions of miles. But now we are enabled to draw a remarkable inference. We know the size of the orbits, and we know the time in which the revolutions are accomplished. It is the mathematician who enables the mass of the bodies to be determined, and the result is not a little astonishing. It tells us that the mass of the two component stars which form Mizar is not less than forty times as great as the mass of the sun. Here is indeed a result equally striking on account of the method by which it is obtained and of the startling character of the conception to which it leads. Remember that in all this the distance of the star from the earth is not concerned, for the results at which we have arrived are absolutely independent of the distance at which the star may happen to be placed. We already knew the masses of some few binary stars by the application of the older process, but in all such cases it was necessary that we should have a previous knowledge of the star's distance. This is always a precarious element, and in the majority of cases it is wholly out of our power to discover it. Now, however, we are entitled to expect large additions to our knowledge of the stars, their masses, and their movements, notwithstanding the fact that the distances may be too vast to be appreciated by any means at our disposal.

The instances that have been given will suffice to show the versatility of the new method. It is the alliance of photography with spectroscopy that makes the present time so full of promise. The improvement of the two arts has gone on simultaneously, and the quantity of detail that is contained in such photographs of stellar spectra as those which have been recently obtained by Professor Pickering and by Mr. Lockyer shows the immensity of the field that now invites exploration.—*Fortnightly Review*.

DESIGN FOR AN ALPHABET BY JAMES WEST.

THE alphabet here shown has been designed in a style corresponding with that which was so popular in Germany in the sixteenth century. The letters in the original drawing are nearly three inches high, and they are reproduced by process in any size.

We are indebted to the *Building News* for our illustrations. They contain many suggestions for lovers of this kind of decorative art.

THE NEW KHEDEVE OF EGYPT.

MEHEMET TEWFIK PASHA, Khedive of Egypt, son of Ismail, whom he succeeded on June 26, 1879, after the forced abdication of his father, died on the 7th of January, at half past seven o'clock in the evening, of double pneumonia, brought on by influenza and complicated with albuminuria. He was thirty-eight years of age and had reigned twelve years. His death occurred at the palace of Helwan, situated upon the Nile, at twelve miles from Cairo. His body was brought thence to the palace of Abdin, at the capital. His obsequies took place on the 8th, in the presence of a large crowd of people, at the necropolis of Imam Chafei. This latter is named after Mohammed ebn Edris el Chaffei, the founder of the sect of Chaffaites, which is very extensive in Egypt, and is one of the four rites of the Mussul-

man religion. It contains, among other mausolea, those of Sultan Mohammed el Kamel, of Ali Bey el Kibir, or "the great," of Ismail Bey, and of the descendants of Mehemet Ali, chief of the present dynasty.

Tewfik leaves one brother, Alim Bey, who, contrary to Mussulman usage, and by virtue of special arrangements adopted some years ago by the sultan, has no claims, and two sons, Abbas Pasha and Mehemet Ali Bey. His second brother, Hassan, who commanded the Egyptian contingent during the Turko-Russian war, died three years ago.

Abbas Pasha, whose portrait we give from *L'Illustration*, the eldest son of Tewfik, and his successor, was born either on the 14th of July or the 31 of January, 1874. We are not yet positively sure as to the exact date of his birth, and the confusion may, up to a certain point, be justified by the difference between the Mussulman calendar and our own, but it is still better explained by the interest that the English have in insisting upon the minority of Tewfik's son in order to impose upon him a guardian of their own choosing. They have already made their choice, since they have gone so far as to give his name, Mr. Milner, the present un-

conceived the aggrandizement of Egypt and its autonomy. He is two years younger than Abbas, and, consequently, less advanced in his studies. The two brothers have a great affection for each other.

As their uncle, Alim Bey, is supposed to have much love for France, it is presumable that this sympathy, common to all the members of the khedival family, will favor our interests toward and against all insinuations.

The kind feeling that all of the Egyptian princes have always had for France is not, moreover, exclusively due to the general habit of sending them among us during the course of their studies. It has its origin in an ensemble of traditions that those of our compatriots who have fulfilled important functions in Egypt have always kept up through their knowledge and integrity. It is not inopportune, for example, to recall the very patriotic influence exercised in the last place by the lamented Mariette, whose death perhaps furnished Tewfik the sole occasion to do a real act of good will. How much the successionship to him was coveted by the English and Germans is well known. It, nevertheless, sufficed our government to present Mr. Maspero as the successor of Mariette to have the Khedive give



ABBAS PASHA, THE NEW RULER OF EGYPT.—FROM A PHOTOGRAPH.

der-secretary of state in the Egyptian cabinet. Turkey, moreover, in its quality of suzerain, has often exacted such tutelage for some time at each change of khedival reign. It is possible that she will exact it again, but that has not prevented Sultan Abdul-Hamid from recognizing Abbas Pasha as the successor of Tewfik, and even from naming him officially the Khedive of Egypt.

Young Abbas learned both of the death of his father and the heritage that had devolved upon him at Vienna, where he and his brother were finishing their studies at the Theresianum. Emperor Francis Joseph, after expressing his condolence to him, put at his disposal a warship at the port of Trieste in order to carry him and his brother as far as to Brindisi, where the two young princes were transferred to a khedival yacht.

Abbas Pasha and his brother left Vienna in the evening of the 8th of January, leaving excellent remembrances among their old fellow pupils. We may add that Prince Abbas, who came to France several times, always showed a great liking for our country. It did not depend upon him whether he should remain here. The motives that led to the preference of a foreign college for his instruction may be conceived.

The same is the case with his brother, Mehemet Ali Bey, who bears the great name of his ancestor, he who

preference to him over all the foreign candidates. This is an interesting and very conclusive remembrancer in favor of the preferences that may be shown us occasionally.

Under the English protectorate great progress has been made in irrigation and an immense increase in the production of cotton and grain has already resulted. Last year a yield of cotton equal to one-quarter of the entire consumption of England was grown in Egypt. She may yet prove to be a competitor of the United States in grain and cotton.

GOLD-COLORED SILVER.

At a recent meeting of the Paris *Académie des Sciences*, says *Iron*, the permanent secretary, Mons. Berthelot, exhibited some specimens of silver bearing an exact resemblance to gold. They had been forwarded to the *Académie* from America by Mons. Carrelly, who describes his methods, and adds that the novel result obtained can easily be nullified. Heat applied to the yellow metal, or even the simple vibration of a hammer blow, suffices to reimpart to it all the ordinary characteristics of silver. By a certain application of light the experimenter has succeeded in producing a variety of silver of purple color which is capable of communicating the yellow tint of gold to the

ordinary white metal. As Mons. Berthelot remarks, it will be better, before proclaiming the discovery of an allotropic state of silver having the appearance of gold, to note that the yellow metal is not pure. According to the analyses received from America, it contains about 3 per cent. of extraneous substances, considered by the experimenter to be iron and citric acid.

THE MANUFACTURE OF DRUMS ON THE COAST OF AFRICA.

The negro races have in all times had a singular predilection for the drum. The negro is enamored with the sound of this instrument, which forms the basis of his music, and he accompanies with it all the great or trivial events of his public or private life. The western coast of Africa, Dahomey more particularly, will demonstrate this to us. There the drum is the national instrument *par excellence*, and there it assumes various forms and dimensions, and varies from the very small

gangan are also the marching drums of the battalions of the Dahomey army, and every battalion has its own. The drums are carried under the left arm and are suspended from the shoulder by a strap. The right hand holds the drumstick. The *kosso* drums follow the battalion instead of preceding it.

The medium sized drums, of which the type is the *ogidigbo*, are especially used in public merrymakings. The sound of this drum, it appears, possesses a very peculiar charm, and the negro cannot hear it without quivering or being seized with a frantic desire to dance. He then accompanies his dance with the following onomatopoeias, giving the sensation of the sound of the instrument: "Gbo, ajagbo, gbo, keh, me, key, o agbo, bo, gha, bo."

As for the drums of large dimensions, they are used exclusively in the great national fetes, and especially upon a declaration of war. The *gdaydoo* is long and bulky, and is ornamented with allegorical carvings. It stands stationary in the interior court yards of the

tory of the coast of Africa, the reader may see the different models that we have described.—*L'Illustration*.

COLOR PHOTOMETRY.*

By Captain ABNEY, C.B., D.C.L., F.R.S.

COLOR has been usually made the subject of reference to empiric and variable standards, a practice which affords results useless for future reference, and only suitable for present immediate wants. What is required is a reference to numbers which are on some standard scale that can easily be reproduced.

According to the lecturer, the color of a body, when viewed in a light of standard quality, is known when (a) its luminosity, (b) its hue, and (c) its purity, or the extent to which it is freed from admixture with white light, are known and expressed by numbers.

The luminosity of a color can be given in absolute number by referring it to the standard of white. Thus, if white light fall on a colored surface and on a surface of some standard white, the luminosity of the former may be expressed in terms of that of the light. It may appear difficult to compare the brightness of two such surfaces, but as a fact the comparison is easily accomplished by causing the light falling on the white surface to be rapidly alternately made brighter and darker than that falling on the colored surface. This can be done by interposing in the beam falling on the white surface rotating sectors with apertures which open and close at will during rotation. The point of equal luminosity can be found by this plan within 1 per cent. Experiments exemplifying the method were made, the brightness of an orange and of a blue pigment being compared with that of a zinc oxide surface which the author uses as standard white. It was also shown, by sending the beams through a trough containing water in which mucin was suspended in minute particles, that the relation only held good for the particular light in which it was measured. Hence the necessity for using a standard light.

The luminosity of the light transmitted through colored translucent bodies was also measured, and the same necessity shown for the use of a standard light.

The standard light recommended was that from the crater of the positive pole of the electric light when full illumination was required, or from a petroleum lamp when the illumination need not be so intense.

The method of measuring the luminosity of light coming through translucent bodies was also shown. A white oblong of paper was placed on a blackened card, a square which occupied half this oblong being pierced in the card, and thus half could be illuminated from the back of the card and the other half by light from the front by placing a rod in the path of the beam to cast a shadow on the first half. The translucent substance was placed close behind the aperture in the card, and the light illuminating the paper, after passage through the translucent medium, was measured by altering the illumination of the other half lighted from the front.

The luminosity of the pure spectrum colors may be measured by what the author calls the color patch apparatus, which is described in the *Phil. Trans.*, 1886, and in his work on "Color Measurement and Mixture." It essentially consists of a collimator, two prisms, a lens, and a camera, on the screen of which a spectrum is brought to a focus. This screen is removed for experiments, and a collecting lens used to recombine the spectrum, and to form an image of the last surface of the second prism on a screen some four feet off. A slide with a slit passed through the spectrum causes the white patch to become a color patch of monochromatic light due to the particular ray traversing the spectrum slit. The white light with which the color is compared is obtained from the light coming through the collimator and reflected from the first surface of the first prism; by means of a mirror and lens, it forms a patch equal in size to, and which can be caused to overlap, the colored patch, or to lie alongside of it. In the first case, a rod placed in the path casts two shadows, one of which is illuminated by the color and the other by the white light; rotating sectors in the path of the latter allow the luminosity to be compared. The light used is the electric light, an image of the crater of the positive pole being formed on the slit of the collimator.

The luminosity of a color is not the same when viewed from all parts of the eye. The center of the eye is that with which observations are usually made; hence the luminosity should be measured with that part of the retina, and it is advisable that no more than 6° of angular measure from the eye should be compared.

The audience were enabled to see the difference in luminosity of a color which was of equal brightness to a certain white when viewed centrally, by shifting the axis of the eye so that the image was received on the retina some 10° away from the center.

The action of the yellow spot was then alluded to. The luminosity of any pigment on paper can be found by rotating it with two of the three colors: red, emerald green, and ultramarine.

These three make a gray which matches a gray formed of black and white. If the luminosity of the three have been accurately determined, by substituting the pigment whose luminosity is required for one of them, another gray can be formed to match a gray consisting of black and white. After measuring the angular aperture of the sectors, the luminosity is determined by calculation; the result is found to agree with the measurement made by the direct method. This is one of the many proofs that the measure of luminosity obtained in the manner described is correct, and not a mere accident.

The color of a pigment can be referred to the spectrum colors by measuring the absorption. In the case of transparent bodies, this is best done by using a double image prism at the end of the collimator, so as to form two spectra on the camera screen. By adjustment, these may be caused to be so exactly one over the other that the same color will pass through a slit in them. After emergence from the slit, the rays from the top spectrum are diverted by a right angle prism, and caught by another which sends them through a lens on to the screen, forming a patch. Another patch, as usual, is formed by the rays from the bottom spectrum. By placing the transparent body in the path of one of these rays, the absorption can be measured by equalizing the brightness of the patches by the sectors and

* A lecture recently delivered before the Chemical Society, London.



THE MANUFACTURE OF DRUMS ON THE COAST OF AFRICA.

tam-tam, placed *ex voto* near large idols, up to the huge drum which appears only in great solemnities.

The generic name of the drum of the African coast is *ilou*, the root of which is the verb *lou*, "to strike." Both the large and small ones, in fact, are struck with a piece of wood curved in the form of the figure 7. They are, in general, manufactured from the trunk of a tree, the *bentonia*, which is hollowed out by means of a hatchet, and the interior of which is burned with a hot iron. The upper part is covered with a goat skin tanned with the juice of the bark of the *Acacia vereck*. This skin is held by cords in the small tam-tams, and is fastened by means of wooden pins in the large instruments. It is stretched more or less by a cord.

The following are the names of a few of the drums: the *kosso*, the *agbay*, the *agboon*, the *ogidigbo*, the *akpink*, the *doondoon*, the *kalaria*, the *dehaykay-ray* and the *gdaydoo*. The following are the uses of some of them: the small ones, or *kosso*, are used by the people in their travels, and the European on his way to Dahomey is often escorted therewith. Its sound quickens the steps of the *hamaquaires*, who accompany it with songs. The *kosso*, the *agbay* and the

royal palace, and in the habitations of the high priests near certain temples.

As soon as war is declared, the feticher pours blood upon the drum or sprinkles it with palm oil or spirits, or covers it with the feathers of fowls offered as a sacrifice. Finally, human skulls are suspended around it.

The object of these ceremonies is to render the genius or spirit of war favorable. Then a warrior, always the same, strikes with redoubled and spaced blows a sort of call to arms whose sound extends to a distance in the country and which brings the soldiers together in a hurry. In return, when the warriors come back from an expedition that has been unsuccessful, the tam-tams become silent. That is a sign of mourning and dissatisfaction, and the fetichers take good care not to depart from this custom.

Every tribe has thus its *gdaydoo*, for which the negro soldier has an adoration and which for him replaces the flag of his corps. A *gdaydoo* taken from an enemy is a trophy like which there is no other, and which the captor carries in triumph.

In our engraving, which represents a drum manufac-

noting the apertures. The absorption of pigments can be measured in the same way by causing one patch to fall on the colored surface and the other on the standard white.

To measure the absorption of pigments an easy plan is to rotate black and white sectors together with variations in the amount of white, and to cause the color patch to fall partly on them and partly on the pigment. The color is varied till it is seen that the gray disk and the pigment reflect the same amount of light.

By both these plans, templates can be cut out, which, when rotated in the spectrum, give the exact color of the pigment on the screen; hence this is a reduction of the true color to absolute numbers, since the color can be reproduced from a reference to a note book. It is to be remarked that the measures are unaffected by any defect in the eye of the observer, or by the kind of light in which they were effected.

The mixture in varying proportions of red, green, and violet of the spectrum makes white. This was shown by placing three slits in standard positions in the spectrum, and altering their apertures till a match was made with a patch of white light alongside.

Any other color can be matched by the mixture of the same three colors, as was shown in matching green, blue, and brown papers.

Since three colors will make white, and the same three colors will make a match with an impure color, every color in nature can evidently be matched by mixing not more than two of these colors with a certain proportion of white light; and if these colors be red and green, or green and violet, the color can be matched by one spectrum color and white light, since there is some intermediate color which has the same hue as the mixture of these two colors. Hence any color, except purple, can be referred to some spectrum color, together with a certain proportion of white light. In the case of purple, the color may be expressed as white light, from which the complementary color is eliminated. Hence any color whatever may be expressed in terms of white light and one spectrum color, the latter in wave lengths, and the former in percentage of luminosity.

This was shown to be the case by interposing between the silvered mirror which reflected the light coming from the first prism, and which formed the white comparison patch, a plain glass mirror which reflected a small percentage of the light on to the color patch, the amount of which could be regulated by sectors. Brown paper was placed in the white patch, and the spectrum color was changed and mixed with the white light till the same color was obtained. The scale of the instrument told the wave length, and, by interposing a rod in the path of beams, the proportional luminosities of the spectrum color and of the white light were determined. A similar match was made by light going through signal green glass, and the complementary color of the light passing through permanganate was determined.

Light coming through properly picked specimens of red, blue, and green glass, and overlapping, may also be made to match a color.

The three glasses covered a square lens, and formed an image on a screen of a circular patch of white light coming through ground glass on a screen. Colors were placed on a white beam alongside, and by altering the amount of the colored glasses exposed, matches were made.

If the dominant wave lengths of the color of these three glasses be known, and also the amount of white light mixed with it, these measures can be noted in terms of these three glasses; and, further, it is possible, by mixing the light coming through the three glasses in various proportions, to obtain a spectrum color mixed with white light for each such mixture. Hence this is a substitute for the spectrum itself. To show this, three similar glasses were placed over apertures suitably cut in a circular card; and, by causing these to rotate in front of an illuminated slit, a sham spectrum was thrown on the screen in which every color was present.

Any color can be reproduced with three rotating sectors of red, green, and blue, when certain proportions of white or black, or both, are mixed with one or other. If the dominant wave lengths and the proportion of white light mixed are known of each such color, the pigment whose color is to be determined can be expressed in numbers as before, and in terms of spectrum colors if desired. This was shown by matching brown paper with red, blue, and green, a little white and black being mixed with the brown.

The importance of using some uniform light was insisted upon throughout, slight deviations in the experiments demonstrating this.

In conclusion, Captain Abney claimed to have demonstrated that the reference of color to numbers was not only possible but easy, and that, to chemists especially, the application was one of almost capital importance. Every one could do it, and the lecturer had an instrument on the stocks which was not so cumbersome as that shown, but which would answer all purposes, he hoped, when complete.

SUNOL.

SUNOL is a bay mare, foaled April 14, 1886. She was bred by Hon. Leland Stanford at his ranch at Palo Alto, in California. She now stands the queen of the trotting world, having trotted over the Stockton track in San Joaquin Co., California, one mile in 2'08 1/4. This is one-half of a second better than Maud S. made her mile. Sunol is the daughter of Electioneer, from Waxana, who was by General Benton [1755]. Waxana is a chestnut mare from Waxy, who was by our greatest of American sires, Lexington, a horse of wonderful merit, from whom descended race horses and trotters.

Electioneer, the sire of Sunol, was by Rysdyk's Hambletonian [10], his dam, the famous Green Mountain Maid.

Mr. Robert Bonner, of New York, is the present owner of Sunol. Sunol stands at the withers sixteen hands one-half inch, and at the junction of the dorsal and lumbar vertebrae sixteen hands two and one-half inches. This is the conformation which insures great speed when coupled with a sound constitution.

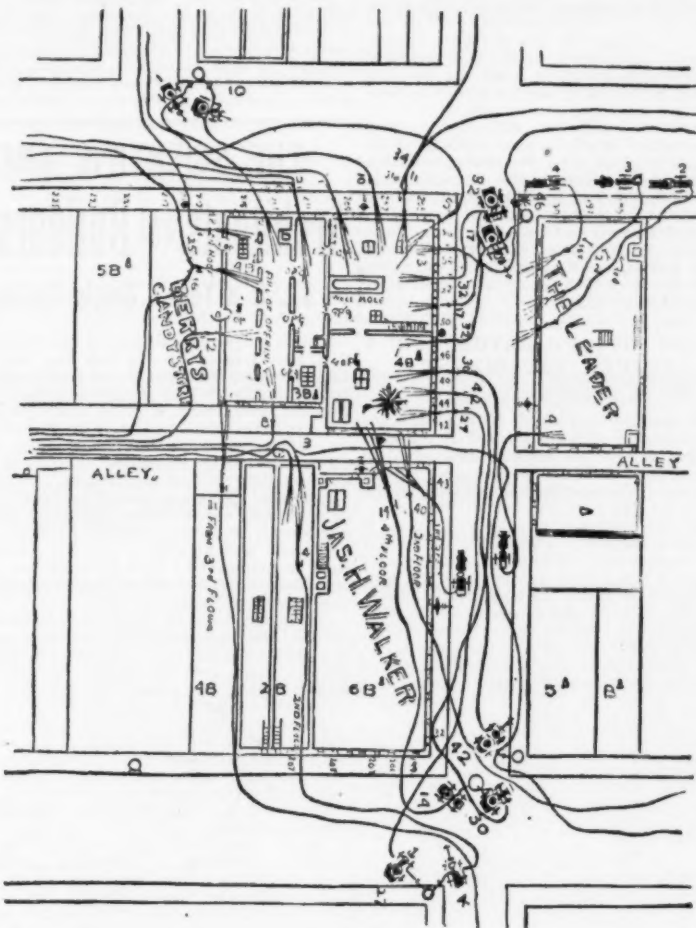
The largest animal known is the rorqual, which is 100 feet in length; the smallest is the twilight monad, which is only the twelve-thousandth of an inch.

EVERY FIRE A STUDY.

CHIEF SWENIE is a fire-fighting strategist, says the Chicago News. When his flaming foe invites battle, he employs all the arts of war to gain the victory. Sometimes he begins the battle by massing his forces at one point and charging directly upon the enemy. Again he throws out a skirmish line or shifts his position so as to take his opponent upon the flank. If necessary he calls up his reserves, and at all times is in constant communication with his chiefs of battalions and captains of companies.

There is this difference, however, between fighting

such as amount of water pressure secured, accidents, incidents, etc. All these data are handed to an expert draughtsman, who proceeds to draw an accurate plan of the fire. He first obtains from the map department an authentic plan of the locality, giving the streets, alleys, courts, building or buildings affected by the flames, whether destroyed or merely scorched, and adjacent buildings. The water department furnishes maps showing location of fire plugs and cisterns and size of water pipe, mains or branches, in the streets. If necessary, the scene of the fire is visited and personal investigation gives him still further information. With all this material the plan of battle is depicted.



MAP OF THE SIEGEL-COOPER FIRE.

fire and fighting armies. Commanders of opposing armies are fully informed of each other's movements days before the meeting and draw up their plans of battle accordingly. Not so with Chief Swenie. Fires advance under cover, every move is hid from view, until they are ready for the fight. Then comes the burst of smoke, the volley of flame, and the chief is suddenly called upon to give battle. Plan and execution with him must be simultaneous; he must think and act while thinking. Yet he has his plan of battle complete in every detail, though it is made up and placed on paper after the battle has been fought. The captain of every engine company makes a report of the fire—as far as his company is concerned—to his chief of battalion, to be forwarded to Chief Swenie. That report gives the time the alarm was received, the fire plug to which the engine was connected, the direction and lead of the line of hose and any changes in the position of the engine, together with other information.

Every piece of apparatus which had anything to do with the fire is located and the lines of hose leading to the fire are shown by lines reaching from the engine to the place occupied by the pipemen. Where the line runs through a building, the floor to which the lead was carried and from which the stream was thrown is properly designated. Thus, in the plan of the Siegel-Cooper fire of August 3 last year, a section of which is shown in the cut, the line of hose from Engine No. 14 was carried through the store of James H. Walker & Co., on the fourth floor, while chemical Engine No. 9 worked part of the time from the second and then from the third floors, and chemical Nos. 4, 3 and 2 carried their hose through the "The Leader" on the first, second and third stories respectively. The large star designates the place where the fire started, and the spiked spot shows the fire alarm box from which the alarm was rung up.

At the Siegel-Cooper fire there were twenty-five en-



SUNOL.

gines, five hook and ladder companies, and six chemicals, and the concentration of this force of fire quenchers upon a comparatively small area is most graphically demonstrated by the plan which was made of that memorable conflagration. Even a casual examination of the diagram is interesting. It is curious to note that the hose from Engine No. 25, which stood at the corner of Jackson street and Plymouth place, and the hose from Engine No. 16, at the corner of Wabash avenue and Jackson street, met on the roof of Barry's candy store and were there connected by a Siamese coupling, so that the combined streams could force the water to the seat of the fire. To Chief Swenie the diagram is of great value, and he studies each one long and earnestly. The plan places before him in compact and legible form the story of the fight, and he examines every part to see wherein he might have made his line of battle stronger. If any engine did slack work, he notes its relative and absolute position, its distance from the fire, the size of the water main to which the fire plug was connected, and draws his conclusions accordingly.

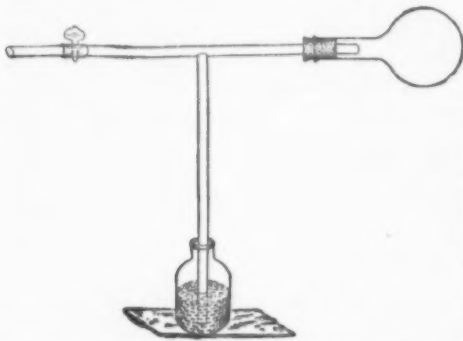
A tabulated statement which is attached to every diagram gives the names, numbers and stations of all the apparatus which responded to the alarm, the time the alarm was turned in, whether the response was made to a first, second, third, or special call, the officers in command, the direction of the wind and any information which cannot be well told by a diagram. Thus the diagram and statement give a description of the complete plan of battle, and Chicago is the only city whose fire chief is able to tell the story of a fight with fire with a war map before him.

A SIMPLE FORM OF APPARATUS FOR A COMMON LECTURE EXPERIMENT.

By W. A. NOYES.

THE apparatus usually employed to demonstrate that the volume of sulphur dioxide formed by burning sulphur equals the volume of oxygen consumed is expensive and somewhat difficult to manage. I have found that the simple arrangement illustrated below answers excellently for the purpose.

In the flask, having a capacity of 250 to 300 c. c., is placed a small piece of sulphur. The flask is then filled with oxygen by displacement of the air. The rubber stopper on the end of the T-tube is then inserted, and by means of the water air pump the flask is exhausted till the mercury rises to a height of about 300 mm. in the lower arm of the tube. After closing the stop cock and placing a mark at the top of the mercury in the tube, the sulphur is ignited by heating the flask with a small flame. The combustion takes place quietly, and



when it is completed, the flask, being thin, cools quickly to its original temperature. When cold the mercury will stand very nearly at the same level as before the combustion, usually a very little higher.—*Amer. Chem. Jour.*

A DELICATE TEST FOR ALUM IN POTABLE WATER.

By ELLEN H. RICHARDS.

IN 1878-79, while making examinations of some food materials for the State Board of Health of Massachusetts, it was necessary to test for alum in bread, and also in baking powders, in the presence of sodium carbonate. The method which was found to be uniformly successful is given on page 161 of "Food Materials and their Adulterations" (Estes & Lauriat, Boston, 1886).

When alum came into use in various methods of purifying water on a large scale, it became important to find a test for it of as great delicacy as that for ammonia; for by the usual methods chemists had often reported no alum in these filtered waters.

Mr. George L. Heath, Assistant in Sanitary Chemistry in 1888-1890, successfully modified the logwood test for alum referred to above, so that it can be applied to potable waters.

On the addition of alum to natural waters, there is a precipitation of alumina in proportion to the amount of carbonates or bicarbonates present in the water. It is, of course, only the alum in excess of the amount decomposed that is to be tested for. The precipitation of the alumina is a gradual process, and a water that will give the test for alum immediately after filtering may give none after twenty-four hours, since the alum may have been all decomposed in the mean time. It is not infrequently noted that the effluents from filters using alum, which are originally clear, become cloudy on standing, in consequence of the separation of aluminum hydrate.

On the addition of alum to brown surface waters there is also a precipitation of alumina by the coloring matters, tannin, or other substances, and in this case also only the excess of alum is to be tested for. For instance, a sample of the Cochituate supply, of moderately deep color, to which 25 milligrammes of alum to the liter had been added, when filtered gave no reaction for alum, even when 25 liters were concentrated for the test. An addition of 30 milligrammes to the liter could be detected without difficulty.

The method is as follows: To 25 c. c. of the water to be tested (concentrated from one liter or more, if necessary) is added a few drops of freshly prepared logwood

decoction; any alkali is neutralized and the color is brightened by the addition of two or three drops of acetic acid. By comparison with standard solutions, the amount of alum present may be determined. One part of alum in 1,000,000 of water can be detected with certainty. In cases of greater dilution, concentration of several liters may be necessary to obtain a decisive test. The logwood chips yield the right color only after having been treated with boiling water two or three times, and rejecting the successive decoctions. The first portion gives a yellow color, the third or fourth usually a deep red.—*Technology Quarterly.*

STRANGE to say, they have been having a grain blockade in Russia, at the same time with the famine. A German journal says that the present distress there seems largely due to inability to transport grain from one part of that country to another. While considerable districts had very poor crops, others had a fair and some even a large production of grain.

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